

T E R R A

MAGAZINE OF THE
NATURAL HISTORY MUSEUM
OF LOS ANGELES COUNTY

VOLUME 30, NUMBER 2
WINTER 1991



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COVER: Eggs from the collection of the Western Foundation For Vertebrate Zoology, Los Angeles. Photo by Clark Sumida.

TERRA

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Museum on the Move

GRANTS

■ **RALPH J. WEILER FOUNDATION SUPPORTS RESEARCH ON ALL-FEMALE LIZARDS AND DECAPOD CRUSTACEANS** Dr. Robert L. Bezy, Curator, Section of Herpetology, has received a grant of \$12,600 from the Ralph J. Weiler Foundation for field research in Central America and Mexico to study unisexual populations of night lizards (see *TERRA* vol. 28, # 1, Fall 1989, p. 29-34). Dr. Bezy will be making detailed comparisons of animals from areas with and without males to determine whether the unisexual populations are of hybrid origin. The work will be centered in Costa Rica, where two species of all-female night lizards are found in tropical lowland forests, a habitat that is rapidly disappearing throughout Latin America.

The Weiler Foundation has also granted \$10,000 to Dr. Joel W. Martin for partial funding of an expedition to study the decapod crustaceans of Cocos Island, Costa Rica. Cocos is the only rainforest island in the eastern Pacific and is thought to have been the setting for Robert Louis Stevenson's book *Treasure Island*. Dr. Martin will be taking a small team of scientists to Cocos in 1993 to photograph and collect crabs, shrimps, lobsters, and other marine invertebrates.

■ **NATIONAL SCIENCE FOUNDATION FUNDS RESEARCH ON SMALL CRUSTACEANS** The National Science Foundation has awarded a grant of \$88,843 to Dr. Joel W. Martin, Associate Curator of Invertebrates. The grant is to fund Dr. Martin's research into the relationships of small, freshwater crustaceans called branchiopods. Branchiopods are a morpho-

logically diverse group of animals that are among the most primitive of the living crustaceans. The group includes such common animals as fairy or brine shrimp, tadpole shrimp, clam shrimp, and a variety of lesser known animals. The research will encompass analyses of relationships based on anatomical and molecular systematic data. Dr. Martin will be collecting animals in California and New England, and will be working with colleagues at Florida State University and U.C. Riverside.

ACQUISITIONS

■ CHESTER STOCK LIBRARY RECEIVES HOWARD PAPERS

The Chester Stock Memorial Library of the George C. Page Museum has recently received a significant gift of documents from Dr. Hildegard Howard, Chief Curator Emeritus of Earth Sciences. Dr. Howard's gift consists of manuscripts, reprints, newspaper articles, correspondence and her personal research notes on the avifauna of the Rancho La Brea Tar Pits. The gift of Dr. Howard's papers is a welcome addition to the archival collections of the Page Museum, and will be of great help to future researchers in the field of avian paleontology.

■ HISTORY DIVISION LUCKS OUT

The General Americana Section of the History Division has recently acquired a collection of coin-operated gambling machines from Mr. Mel Hindin, a docent with the museum's Education Division since 1984. Mr. Hindin donated 13 slot machines from a collection he assembled over a number of years.

Gambling was an essential part of the history of the American West. Considered by some as an activity inspired by the devil, it nonetheless thrived as an irresistible attraction to many seeking their fortunes in the Old West.

Dr. Craig Black (left), Director of the Natural History Museum and its satellites, with George C. Page, namesake and donor of the Page Museum of La Brea Discoveries, at Mr. Page's 90th birthday celebration.

OPPOSITE ►

Crimson hydrogen gas escaping from the sun's surface during the eclipse.



Dick Meier



Gambling, in fact, remains one of the very few activities shared by the miners and cowboys of old and their twentieth-century descendants, lured today to Las Vegas, Reno, Laughlin, and Lake Tahoe.

In the early nineteenth century, coin-operated gambling devices were sanctioned by law in many American communities. Most were regulated and taxed by local authorities. The machines' association with organized crime, however, caused a national moral outcry during the early 1950s. As

a result, every state except Nevada enacted legislation making ownership of slot machines a criminal act, and machines were destroyed by the thousands. Finally, in the late 1970s, ownership of vintage machines was legalized.

Given the turbulent history of these curious and controversial devices, Mr. Hinden's donation is an important addition to the History Division's collection of games and other recreational artifacts. These machines, mostly manufactured in the 1930s and 1940s, represent some of the renowned

American designers and manufacturers of coin-operated devices during the early and middle twentieth century.

MUSEUM NEWS

■ **TOTAL SOLAR ECLIPSE IN BAJA CALIFORNIA** Museum members travel the earth in search of education and adventure, but there wasn't far to travel on July 11, 1991, when 80 members joined the Museum Travel Pro-

gram in Cabo San Lucas, to view a total solar eclipse. Totality lasted six minutes at the observation site, and the sky was completely clear, allowing viewing and photography of the entire outer corona. The corona was extremely bright and large during this eclipse, with elongated streamers and crimson prominences. The deep twilight aura made Venus, Jupiter, and Mercury, as well as the stars Sirius and Betelgeuse, visible at noon. Travel Program offerings for 1992 are listed on this issue's inside back cover.

■ COSTUMES ON THE MOVE

September 29th, 1991 marked the foundation of the History Division's new support group, the American Costume Associates, at the Hollywood Roosevelt Hotel. The association, whose formation coincides with plans for a new state-of-the-art storage and study facility, will promote broader use of collections as the Natural History Museum becomes a center for American socio-historical research through cloth and clothing. The collection contains early Hollywood costumes belonging to Mary Pickford, Harold Lloyd, and Charlie Chaplin. Its holdings also include nineteenth century Hispanic California costumes, including articles from the Sepulveda, Pico, Coronel, Lugo, and Del Valle families; clothing that belonged to Thomas Jefferson; Revolutionary War uniforms; and household textiles such as quilts and coverlets dating from pioneer times.

Members of the American Costume Associates will participate in such activities as organizing the replication of delicate costumes for display, lecture and workshop programs, upgrading mannequins, organizing internships, and providing general support for an upcoming traveling exhibition on footwear. Interested parties should call the Membership Office for further information at 213/744-3426.

DEVELOPMENT

■ **PAGE FOUNDER'S 90TH BIRTHDAY CELEBRATED** On June 23, 1991, the Boards, Fellows, and staff of the Natural History Museum gathered at the George C. Page Museum of La Brea Discoveries to celebrate the 90th birthday of the museum's namesake and donor. Supervisor Edmund D. Edelman, Trustee Richard Call, Alliance Board

This late 1920s bisque Kestner doll is part of the History Division's renowned Morrison Doll Collection. Although makers' marks are often traceable, costumes are examined to date dolls, or to infer their function, whether recreational, religious, ceremonial, or decorative. This doll will be featured in the museum's upcoming traveling exhibition on footwear.



Dick Meier

member Ray McCullough, and staff members Judy Chovan and Barbara Parkhurst shared stories of personal encounters with Mr. Page that illustrate his determination, adventurous spirit, and compassion. Guests shared a saber-toothed cat birthday cake and toasted the honoree at this special museum family event.

■ **MUSEUM RECEIVES GIFTS AND GRANTS** The Pacific Telesis Foundation has given a major grant to fund the Natural History Museum's Classroom Collections program. This lending service provides museum models

and artifacts to teachers throughout southern California for use in their classrooms. For information about Classroom Collections, call Karen Himes at 213/744-3345.

The Mattel Foundation has provided a major grant in support of the Ralph M. Parsons Discovery Center, the museum's hands-on learning center that allows children to explore and discover at their own pace, and encourages family interaction.

National Medical Enterprises, Inc., which has supported the Moveable Museum Special Education Program since the early 1980s, has recently expanded its patronage to include funding for programs directed at senior citizens. NME employee volunteers will join the museum's own to bring the richness of our collections to those who cannot visit us at Exposition Park. Generous gifts from the Kenneth T. and Eileen L. Norris Foundation and the Sidney Stern Memorial Trust will also support the Moveable Museum this year, sending trained docents with touchable artifacts and specimens to classrooms throughout greater Los Angeles.

Significant gifts from the Whittier Foundation, the Jacobs Family Foundation, and the Joseph Drown Foundation are enabling talented teenagers to experience the Museum Research Apprentice Program. The participants will work with museum curators learning ecological research techniques and will receive career counseling in the sciences. Special emphasis is placed on the inclusion of minority group members during recruitment for the apprentices. The Golden State Minority Foundation, the Mary Pickford Foundation, the Ann Peppers Foundation, the Shell Oil Company Foundation, the Stein Foundation, and Mitsui Manufacturers Bank are also recognized for contributions to this effort.

■ **NEW BUSINESS ASSOCIATES** The museum is pleased to welcome IMPERIAL TOY COMPANY, GRIFFIN HOMES, and CHRISTENSEN, WHITE, MILLER, FINK & JACOBS as Business Associates.

■ **NEW FELLOWS** The Fellows enjoyed a private curatorial talk at the opening of Dinosaurs Past and Present and Dinosaurs — A Global View in June, celebrated the opening of Remember the Children with guests of the U.S. Holocaust Memorial Museum, and admired two special exhibits in the Gem and Mineral Hall with James Lucey, a diamond expert from the Gemological Institute of America. The fall Fellow calendar includes a trip aboard an oceanographic research vessel, a nostalgic trip to the Hollywood Roosevelt Hotel to learn about film costumes, dinner with experts on Mayan culture, a reception for Meave Leakey and Alan Walker, and a trip to Sacramento to meet the politicians. New Fellows who will have the opportunity to join these adventures include Jona and Doretta Goldrich, the Joseph M. Knott family, Arnold and Anita Lorber, Nathan and Lilly Shapell, Mr. and Mrs. Sanford Sigoloff, and Alan Ziegler and family.

The Egg Came First

by Lloyd Kiff

AT THE TURN OF THE CENTURY, America's best-known ornithologist, Frank Chapman, remarked that "the only two interesting things about bird eggshells are what they come in and what comes in them." Chapman's view reflected the contempt that many professional ornithologists once held for the study of eggs, or "oology," as its adherents called it. Chapman would no doubt be surprised to find that the avian egg, once considered an object of interest only to hobbyists, has become one of the most intensively used types of natural history specimens in recent years.

Bird egg collections were amassed in North America by a loose army of private collectors mostly between 1880 and 1940, with a handful of practitioners persisting until about 1960. During this peri-

od, the hobby was a virtual rite of passage for young boys, both here and in England, and some of them never outgrew the pursuit. As many as a thousand serious adult collectors existed at one time or another in North America. Eventually, legal restrictions on private collecting and changes in societal attitudes towards nature resulted in the demise of the hobby. Currently, bird eggs are collected in this country only by professional biologists, mostly for one-time-only analytical purposes (a lamentable trend, given the multitude of uses for museum specimens).

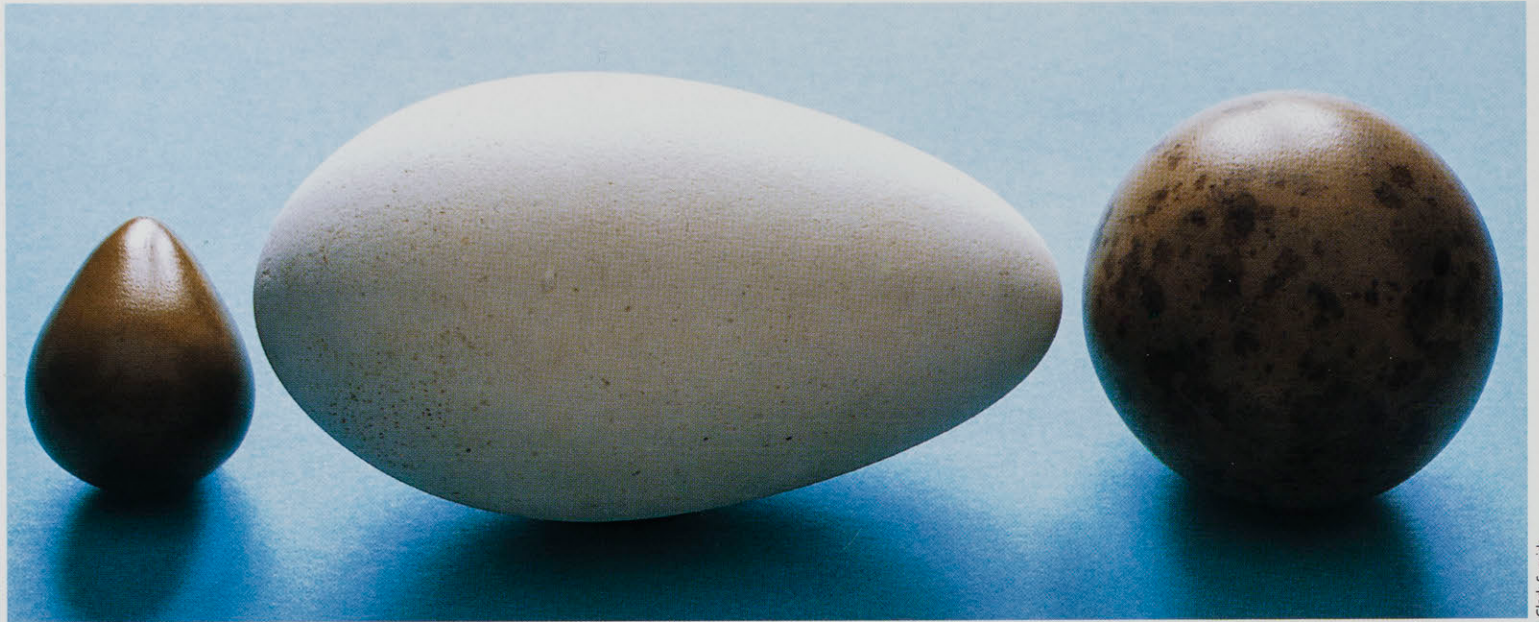
Although its adherents insisted that oology was a legitimate science, over time the term "oologist" came to refer more to the collector of bird eggs than to those who studied them. Most oologists found more pleasure in the means than in the purported ends of oology. Their interest was largely con-

Extremes in egg size: the two-gallon capacity egg of Madagascar's extinct elephantbird (*Aepyornis maximus*) dwarfs a hummingbird egg.



Clark Sumida





Clark Sumida

fined to the acquisition and organization of their trophies, and the oological literature ran mainly to anecdotal accounts of collecting trips sprinkled with occasional spicy discourses about the fraudulent practices of certain other collectors. In general, the accumulated literature of North American oology up until the demise of its most important outlet, *The Oologist*, in 1941, now offers more of interest to the historian than to contemporary biologists.

Egg collectors were followed by consolidators of many separate collections. These individuals were collectors themselves, but they operated on a more ambitious level. Their efforts to centralize collections were instrumental in ensuring the long-term survival of the specimens. Neither the original collectors of eggs nor the later collectors of egg collections were necessarily formal scholars, although they were interested in the results of serious studies on eggs. It is doubtful that they would have ever tackled the diverse types of research currently being conducted on eggs. Yet the fact that they carefully recorded data with their eggs did justify their claim to be making a contribution to science. Nowadays, relatively few of the researchers who study eggs have the drive of a compulsive collector, or even much awareness of where the museum specimens originally came from, but they obviously could not conduct their studies without the earlier labors of the oologists.

Museum egg specimens are actually empty eggshells, whose contents, including the yolk, egg-white (albumen), and embryo have been removed. Air is forced into the egg through a single tiny hole in its side, and the contents are displaced out of the same hole by the resulting internal pressure. Under the right conditions, empty eggshells can survive indefinitely. An eggshell of the extinct elephantbird of

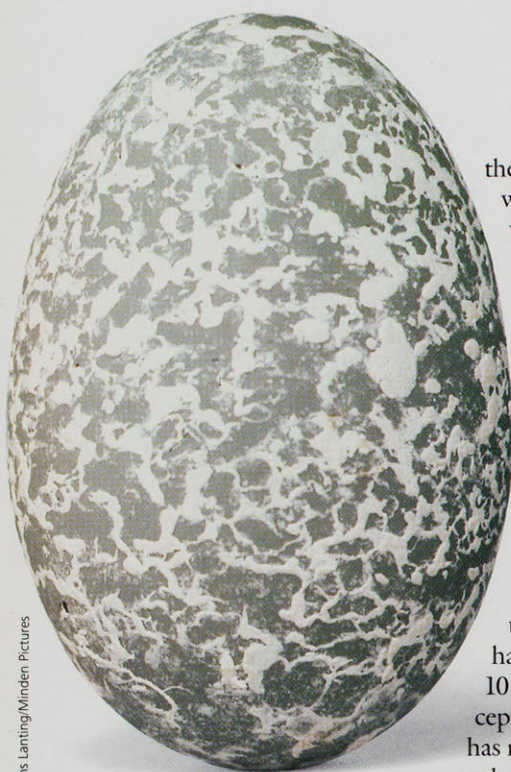
Madagascar in one collection has been dated at 14,000 years, and we recently obtained very healthy-looking Pleistocene-aged California Condor eggshell fragments from caves in the Grand Canyon. Oologists typically collected eggs as whole clutches, or "sets," which facilitates the study of intracatch variation in egg size and color. Most bird species replace lost clutches fairly promptly.

Typically, details on the locality and date of collection, number of eggs, name of the collector, stage of incubation, and remarks on the nest type and location were recorded for each egg set by the collector. Most serious North American collectors had personalized data cards, or "data slips," which had a gratifying similarity in size and data categories. European collectors used much smaller and easily lost data tags, and most recorded only minimal data. Until the late 1800s, it was the custom to inscribe the essential data on the eggs themselves, at least for larger specimens, but this required a level of calligraphic skill seldom exhibited by later generations of collectors.

The Western Foundation of Vertebrate Zoology was formed in 1956 by five amateur naturalist-businessmen, who wanted a place to deposit their personal egg collections. Four of them, C.V. Duff, Ed Harrison, J.R. Pemberton, and William Sheffler, had served at one time or another on the Board of Governors of the Natural History Museum of Los Angeles County, and they realized that the museum (like most others in the 1950s) was not particularly interested in receiving egg collections. The Western Foundation became a favored depository for egg collections, and over the intervening years the collections of almost 300 individuals have come to rest here. The Western Foundation's collection is by far

Extremes in shapes are shown by eggs of the Pheasant-tailed Jacana, flamingo, and a bustard (left to right).

◀ OPPOSITE
Extremes in eggshell texture.



Frans Lanting/Minden Pictures

The Wedgewood China egg of South America's Guira Cuckoo.

the largest in North America, and possibly in the world (an inventory of the collection at the venerable British Museum, planned for later this year, should settle this point of frequent speculation once and for all). About 175,000 egg sets with complete scientific data are now housed by the Western Foundation. Including specimens without full data, the total holdings are around 800,000 individual eggs.

Since the WFVZ is essentially the principal center of oological research in the world, it is in a unique position to follow research on museum egg specimens. We never fail to be impressed by the diversity of the uses to which eggs are put. Certain specimens have been used by researchers from as many as 10 different academic disciplines. Since its inception, the Western Foundation egg collection has now been used in over 3,000 research projects, and well over a hundred graduate theses and dissertations have been based in large part upon studies of the specimens.

Frequent uses of our egg collection include the identification of eggshell fragments and the photographing of eggs for publications. Recently, the Western Foundation accepted the job of supplying the egg measurements and descriptions for the "Birds of North America," a proposed series of definitive biographies of all the bird species known to breed on the North American continent. Egg collections are being increasingly consulted by archaeologists interested in learning what kinds of fowl their prehistoric study subjects ate or worshipped in the past, based on bits of eggshell found in kitchen middens and other aboriginal sites.

The most obvious practice in egg research, aside from comparisons of egg color, has been to measure eggs. The three most common egg measurements are length, breadth, and weight (mass). The latter is usually expressed as *relative* egg weight, or as a percentage of adult female body weight, in order to permit comparisons between species of disparate sizes. Measurements yield numbers, which yield generalizations that can be supported by tests of statistical significance. Departures from generalized relationships often reveal specializations which may be of interest to ecologists, physiologists, and others interested in evolutionary processes.

Egg collections represent a vast reservoir of information for the students of these topics and served as the basis for Max Schönwetter's monumental *Handbuch der Oölogie*, a compilation of basic measurements and other information on bird eggs of the world. This 45-volume work, appearing in installments between 1960 and 1988, has taken almost two lifetimes (Schönwetter's and that of his successor, Wilhelm Meise) to compile and publish.

The German ornithologist Oscar Heinroth was the first to recognize that the egg is the most basic comparative unit in avian reproduction. In 1922 he published the egg weights, adult body weights, incubation periods, and clutch sizes for 427 bird species from all parts of the world. Among other conclusions, he found that large birds lay relatively smaller eggs than small birds, and he divided birds into *altricial* types (whose chicks hatch naked and require extended parental care) and *precocial* types (whose chicks hatch covered with down and gain independence shortly after hatching). Re-working Heinroth's data in the 1930s, Sir Julian Huxley showed that the relationship between bird size and egg size is a logarithmic one and that it is very consistent within particular bird families.

Over the past two decades, physiologist Hermann Rahn and his colleagues at the State University of New York at Buffalo have taken this line of research a notch higher, exploring the interrelationships between egg size and other aspects of reproduction. Drawing upon the data tabulated in the Schönwetter *Handbuch*, they have established allometric equations relating egg mass (and therefore egg dimensions) to egg density, eggshell thickness, incubation time, egg surface area, pore density, basic metabolic rate, and, of course, adult body size. Rahn's work is an elegant bridge between the information contained in empty museum eggshells and the physiological and behavioral data obtained from the study of living birds. One of his conclusions is that the extinct elephantbirds (*Aepyornis*) of Madagascar must have weighed over a ton and that their incubation period must have lasted for at least 100 days, based on the size of their immense eggs.

Egg size varies primarily as a function of body size, but it can also reflect the age, physiological condition, and diet of the female. Other variations in egg size can occur with the position in the clutch, the time of the season, the number of eggs in the clutch, the clutch number within a season, and quality of the habitat. Some of these sources of variation can be examined in egg collections, while others require actual field studies. Museum specimens have been used in numerous investigations of geographic variation in egg size. Because of the strong genetic component in egg size, such variations usually parallel equivalent trends in adult female size. For larger species, egg collections are far more practical tools for such studies than are collections of actual bird specimens, since few museums can afford the space to store many examples of the actual birds.

There does not appear to be any consistent trend in the types of variation in egg size among birds in general, but in each species the observed pattern appears to be part of a broader reproductive strategy. For example, ecologists have divided animals into "r-selected species", which survive through



Frans Lanting/Minden Pictures

OPPOSITE ►

Unlike related plover species of the widespread genus *Vanellus*, which lay dark olive-brown eggs, the reddish-brown eggs of India's Yellow-wattled Lapwings are well matched to the red lateritic soils on which the birds nest.

high productivity of young, and "K-selected species", which survive through longevity. Examples of the former include quails and ducks, which produce many relatively small eggs and invest little energy in caring for their young. The latter group includes birds of prey and many tropical bird species, which lay fewer but larger eggs per clutch and invest a large amount of energy to ensure the successful fledging of their chicks. According to ecological theory, r-type selection should predominate in unpredictable environmental conditions, whereas K-type selection should prevail in more climatically stable areas, as on islands, or in tropical regions. This sort of hypothesis can be tested with large museum egg collections, and is, in fact, borne out by egg size trends in Scrub Jays. They lay fewer, but relatively larger eggs on Santa Cruz Island and in Florida, and larger clutches of relatively smaller eggs in more unpredictable environments on the California mainland and in the Rocky Mountains.

Probably no other topic has generated more lively debate among ornithologists over the past 50 years than the factors that regulate clutch size, or the number of eggs laid per nesting attempt. Clutch size is one of the most easily quantified measures of a species' reproductive rate. Egg collections provide larger samples than an individual researcher might hope to obtain through personal field work, but one

must be aware of the potential biases of the old-time collectors, non-scientists gathering specimens in a decidedly non-random manner. Collectors favored the unusual, including extra large clutches, and spurned the mundane, which, to them, included clutches with fewer eggs than they thought "normal" for the species. This

sometimes resulted in higher average clutch sizes in egg collections than is often observed in nature. This tendency was most pronounced with birds that nested in colonies, where the collector could make a leisurely choice among a virtually unlimited supply of eggs. It was less likely with scarce species for which even a single egg was better than nothing at all. Too, such biases were offset by the collecting of incomplete sets by inexperienced gatherers. Thus the clutch

size averages for common songbird species from collections are often very close to those found from field studies.

Bird eggs have an undeniable aesthetic attraction to collectors and non-collectors alike. For natural objects, eggs exhibit a surprising range of colors. It is always surprising to me that artists have not borrowed the striking patterns of certain eggshells for commercial or purely aesthetic purposes.

Defense against predation is the most important factor in egg color for most small birds. The prominent British ornithologist David Lack showed that egg color in thrushes is generally correlated with the nest site — white eggs in this group are found almost solely in hidden sites, and spotted eggs occur in nests placed in more open situations. A study of neotropical egg color by the Brazilian ornithologist Yoshika Oniki found that blue eggs occur in deep, thick-walled nests in situations where they may resemble dappled sunlight falling on leaves. Tests of global hypotheses of this type rely heavily on the resources of large egg collections and their ancillary data, coupled with the extensive literature on birds.

It has been shown repeatedly that the markings on eggs have cryptic value. For example Canadian gulls eat the white eggs of puffins more frequently than the highly marked but more numerous eggs of murrelets. The eminent behaviorist, Niko Tinbergen, and his colleagues demonstrated that Black-headed Gull eggs painted solid white or solid khaki were preyed upon more often than were normal spotted eggs. Nicolaas Verbeek has recently studied the eggs of Northwestern Crows and Glaucous-winged Gulls in British Columbia in regard to differential predation. In both of these unrelated species, the last-laid egg in the clutch is usually paler in color than the other eggs. Verbeek found that these eggs are preyed upon more often than the other eggs (he called it the "odd one out" syndrome). This is of adaptive significance because last-laid eggs are less likely to hatch than are the other eggs in the clutch. This is because they hatch asynchronously in the order they were laid. As the first chicks emerge, the adults leave to hunt food for them. Any unhatched egg thus get less incubation and is less likely to hatch. If the last chick does succeed in hatching, it is at a competitive disadvantage among its older, bigger siblings. In the case of the gulls, the paler eggs are also smaller in size. Thus, in an adaptive sense, the crows and gulls offer up their least valuable egg to predators. An examination of the Western Foundation egg collection indicates that the odd-colored-egg strategy may occur among several other families of birds, including weaver finches, blackbirds, and some thrushes.

In certain ground-nesting birds from entirely different families, eggs appear to actually match the substrate upon which they are laid. Within the virtually cosmopolitan plover genus *Vanellus*, most spe-



A cross section of a DDE-thinned American Kestrel eggshell magnified 300 times by a scanning electron microscope.





European Cuckoos are host parasites; they lay their eggs in the nests of other birds, who then raise the young cuckoos. Some cuckoos tend to choose hosts with eggs of color patterns similar to their own, reducing the chances of their eggs being rejected by the host. In the photo, eggs of five different European Cuckoos are on the right, and the eggs of the hosts they chose are on the left.

OPPOSITE ►

The white egg of a puffin (center) is more likely to be taken by predators than the heavily marked eggs of murres.

cies lay dark olive-green eggs heavily blotched with dark spots. In portions of India, however, the resident *Vanellus* species lays richly colored reddish-brown eggs that match the red lateritic soil on which the birds nest. In a drawerful of *Vanellus* eggs of the world, the "different" eggs of the Indian species jump right out at the researcher. Large egg collections should yield other color variations with similar ecological significance.

The eggs of hole and burrow nesters are usually white, perhaps because it makes the eggs more visible to the birds themselves. Experiments with several species have shown that artificially coloring the unmarked eggs of hole-nesting species usually leads to their accidental breakage by the birds from claw punctures or other mechanical injuries. Indeed, examination of the highly glossy, white eggs of burrow-nesting kingfishers and cavity-nesting woodpeckers with a spectrophotometer suggests that they have unusual light reflectance properties. They apparently differ in this aspect from the white eggs of doves, which build open nests.

Egg collections are particularly useful for studying evolutionary adaptations of host parasites — bird species that do not provide any parental care to their young, but lay their eggs in the nests of other species. This behavior has evolved independently at least seven times in birds and is exhibited by species as diverse as cuckoos, the cowbirds of the Americas, Africa's honeyguides (close relatives of woodpeckers), and even a duck species in South America.

The classic example of host parasites is the European Cuckoo, and several authoritative books and a good deal of poetry have been written about its highly specialized lifestyle. Female cuckoos lay in the nests of other birds, usually a small songbird. In many instances, but not all, the cuckoo egg closely resembles that of the host. This is an adaptation to parasitism, since the eggs that most closely match those of the host stand the best chance of being accepted and hatched. Some potential hosts eject or puncture eggs that do not resemble their own, and such selective pressures have led to the evolution of some local cuckoo populations capable of producing eggs of several different color types, each closely matching those of a different host species. A given female lays only a single type of egg, in the "right" host nest, at least when things are going according to evolutionary plan. Cuckoo eggs can be detected, even in very old collections, by their disproportionately heavy shells — apparently an adaptation to resist puncturing by host species. The species has evolved a smaller egg than expected in relation to its body size, presumably to enhance its acceptance by the smaller hosts, but the shell thickness is still that of the much larger ancestral egg. Cowbirds are much less specialized host parasites, and lay eggs of only one color pattern, but they do have thicker shells.





There is considerable interest in cowbird parasitism in the conservation community as the spread of several of these species, facilitated by human modifications of habitat, is becoming an increasing threat to the survival of many North American songbird populations. Indeed, the familiar Brown-headed Cowbird is a relatively recent immigrant to the Pacific Coast region, having shown up here just before the turn of the century, and its advance northward can be reconstructed from the records of parasitized egg sets in the Western Foundation collection. Cowbirds evidently arrived in the Pacific Northwest within the last 40-50 years. Judging from the egg size of the first few sets collected in Oregon, the immigrants were of the small-egged *obscurus* race from coastal California, rather than from the large-egged race *artemisiae* from the Great Basin region. In the case of heavily parasitized species, egg collections can reveal hosts which might be suffering actual population damage from the attentions of the cowbirds.

There is also much current interest in intraspecific parasitism, in which birds lay eggs in the nests of other members of the same species. This seems to be a widespread phenomenon among songbirds, especially those nesting in colonies. In an evolutionary sense, it is a gamble, of course, especially in species that pitch out or otherwise destroy foreign-looking eggs. Museum collections often turn up different-looking eggs within clutches, and while it is tempting to infer that these are laid by foreign females, it cannot be assumed, as the odd eggs are often from the actual owner of the nest, not from an intruder. Although electrophoretic studies of protein structure in egg white have enabled researchers to distinguish the eggs of different females, an equivalent technique is not yet available for empty eggshells. The development of such methodology will open a floodgate of studies on the incidence of intraspecific parasitism.

Museum collections often serve as the source of inspiration for interesting field studies. For example, one cannot help but be amazed at the amount of color polymorphism (fixed color types) among the eggs of certain species of weaver finches (*Ploceus*) and grass warblers (*Prinia*) of Africa. In the case of the weavers, this was originally thought to be a defense against host parasitism by cuckoos, but research suggests that it may be more important in protecting the birds against parasitism by other weaver finches nesting in the same colony. This is less likely to be the case with the grass warblers, which are solitary nesters. Both groups would be excellent subjects for field studies.

The science of ornithology has reached few conclusions about the significance of the shape of bird eggs, other than demonstrating that the pyriform, or pear shape, of the eggs of certain cliff-nesting seabirds such as murres is an advantage, since they roll in a tight circle when bumped (see example

in photo, page 13). Additionally, such eggs are found among shorebirds and other ground-nesting species, since the eggs do not tend to roll out of the nest-scape (a depression scraped in the ground rather than a constructed nest) readily, where they might not be retrieved or even recognized as an egg. Furthermore, these species typically lay four very pointed eggs, arranged compactly so that the small ends are in the middle. One researcher suggested that this arrangement fills the nest, providing thermoregulatory advantages. The theory was that longer, pointed eggs provide more surface contact for the incubating female, furnishing a more efficient warming of the egg contents than if they were spherical (presumably the most parsimonious shape of all in a pure physics context). Yet, working with eggs from the Western Foundation collection, former U.C.L.A. biologist Donald Hoyt showed that the slight differences in surface area between eggs of different shapes would have an almost negligible effect on egg temperature, compared with other factors like nest insulation and incubation patterns, so the jury is still out on this one.

The topic of adaptations in egg texture has also barely been touched, although there is an obvious great diversity in this character, ranging from the highly polished, enamel-like surfaces of tinamou eggs to the heavily corrugated avocado-eggs of the cassowary to the chalky covers of pelican and ani eggs. Researchers will no doubt find that the texture of eggshell surfaces reflects the microenvironment in which the egg must function.

The avian eggshell has been called "nature's perfect package." In addition to providing protection for the developing embryo, it serves as a source of calcium, acts in the exchange of respiratory gases (oxygen and carbon dioxide), slows desiccation, protects against microbial intrusions, and is often camouflaged. The porous microstructure is of particular interest to physiological ecologists, who have found that the eggshell thickness and the density of the pores varies greatly among bird species, depending upon the humidity of the nest environment. Although the most instructive studies on the physiology of eggs are those conducted on whole, viable eggs, empty eggshells can provide useful complementary data and reference material.

Many of the most informative techniques used in egg investigations, especially studies of their complex ultrastructure using scanning electron microscopes, involve the destruction of the specimens. I am fond of telling visitors that we maintain the largest collection of broken eggs in the world. Rather than sacrificing irreplaceable whole eggs, it is much more desirable to use already-broken specimens with complete data. Furthermore, every large museum egg collection contains a number of eggs that never seem to match up properly with a data slip, but that nevertheless are well identified and useful for many

purposes. Such "excess" specimens are great for experimental work. Various researchers, especially graduate students, have frequently "borrowed" (in the sense that one borrows a cigarette) eggs from us to be used for various experiments. For example, actual cowbird eggs can be placed in the nests of potential host species to observe their response, or incubation temperatures can be monitored by placing a thermistor in a museum eggshell (or egg specimen) introduced into an active nest.

All, some, or none of the foregoing egg characteristics may be indicators of evolutionary relationships and thus be of use in avian taxonomy, or the classification of birds. Unfortunately, it is often difficult to separate ancestral characters from more recent adaptations, for example, cryptic coloration, for which a selective advantage seems obvious. Just as many avian taxonomists have rejected eggs as taxonomic tools, egg proponents have been just as insistent that they hold the true answer to evolutionary relationships. At the latter extreme was a paper given at an ornithological society meeting in which the author divided the Class Aves into two main evolutionary lines, those laying white, unmarked eggs and those laying spotted eggs!

Based on his 1958 study of egg color in thrushes, David Lack concluded that it is of little use in taxonomy. Yet many subsequent researchers have used egg color as a generic or species-level character. And more frequently than not, egg characters seem to coincide with taxonomic arrangements based on other characters, as can be seen in such diverse bird groups as the auks and murrelets, tyrant flycatchers, North American sparrows, and African shrikes.

In general, it appears that egg characters are more useful in *confirming* relationships than as primary indicators of them. For many years the validity of Frantz's Nightingale Thrush as a full species distinct from the superficially similar Russet Nightingale Thrush was questioned by many ornithologists. Western Foundation expeditions to Mexico in the early 1960s showed that there were indeed two different forms, the tip-off being the discovery that the latter species laid unspotted, deep robin's-egg blue eggs, whereas the eggs of Frantz's Nightingale Thrush were pale blue mottled with brownish cinnamon spots. Further examination of museum study skins, coupled with studies of the living birds, showed numerous other distinctions between the two species, and no one now doubts that they should be regarded as separate.

Similarly, the relationships of the Black-and-Yellow Silky Flycatcher of the wet montane forests of Costa Rica and western Panama were repeatedly questioned by taxonomists for a century — some called it a thrush, some a silky-flycatcher, and others could not place it at all. During the course of field work near the crater of Costa Rica's Volcan Poás in

◀ OPPOSITE

Extreme color polymorphism in African Tawny-flanked Prinia (top) and Black-headed Weaver (bottom) eggs is thought to aid in recognition and may be a defense against parasitism. Each female lays eggs of only a single color type.



Western Foundation of Vertebrate Zoology founder Ed Harrison shows off some of the foundation's collection of 800,000 eggs.

1972, I was fortunate to find the first known nest and eggs of this species. The eggs were grayish-white with a suffusion of extremely fine grayish and purplish-black pinhead-sized dots and thus identical to those of the three other species in the small silky-flycatcher family, *Ptilonotidae*. The other species include the Phainopepla, which occurs in the dry Mojave Desert and coastal areas of southern California, the Gray Silky-flycatcher of northern Mexico's middle elevation dry pine-oak woodlands, and the beautiful Long-tailed Silky-flycatcher, which is also endemic to the montane portions of Costa Rica and Panamá. It is difficult to find a common environmental thread among these diverse habitats, and it is reasonable to conclude that egg color in this group of birds is of taxonomic significance.

In any case, there is no question that egg color is genetically determined. In fact, based on their study of Village Weaverbirds in a U.C.L.A. aviary, Nicolas and Elsie Collias found that egg spotting in this species is attributable to a single gene and that ground color was due to two others. This had already been realized, albeit intuitively, by the prominent egg collector Griffing Bancroft, who wrote of oologists that "Our weakness is avarice for brilliantly marked eggs, but in our

search for them we find only accumulating indication that the general factor responsible for pattern is heredity."

Increasingly, biologists are relying more heavily on studies of DNA to answer taxonomic questions. Although such research is valuable, it remains to be seen whether it will lead to a greater consensus about evolutionary relationships than has resulted from other approaches. If someone were to devise a non-destructive technique to extract analyzable DNA from the membranes of museum eggshells, an enormous number of previously untapped specimens would become available for analysis.

More than half of the research conducted at the Western Foundation involves the use of data slips. Without them, empty eggshells are mere curiosities. These data are particularly useful in delineating breeding times of birds, and collection dates can reveal latitudinal and altitudinal patterns in lengths of breeding seasons. Egg dates can also provide a handy starting point for studies of single species.

Such data may also have applied value; for example, there was considerable concern about the effects of sonic booms on animals of the California Channel Islands over which the space shuttle was to pass. Rumors circulated to the effect that the shock would be so loud as to break the eggs of nesting seabirds. We gathered data to help the U.S. Air Force decide how to schedule the space shuttle missions so that breeding birds would not be harmed. Fortunately, the shuttle's effects turned out to be quite mild compared to the apocalyptic effects predicted by early critics, but our data have proven to be useful for other management purposes.

Data slips also have been used for comparative purposes. While most woodpeckers make their nest cavities in dead trees, data slips indicate that a few invariably choose living trees. Different subspecies of birds now lumped together as Sage Sparrows place their nests in completely different situations. Perhaps this, along with other characters, indicates that they are actually separate species. Black-chinned Hummingbirds almost always nest in sycamore trees. Golden Eagles nest in large trees or on cliffs in California, but seem to prefer the former where both are available. Such findings from data slips have management and conservation implications.

The data for the 54 wild-taken California Condor eggs still known to exist have had numerous applications to the present captive breeding program. We know that the captive birds are laying eggs in January, earlier than ever recorded in the wild, that one captive female is laying smaller eggs than any previously recorded, and that the captive eggs in general are slightly smaller in size than wild-laid ones. One condor egg taken illegally in 1939 came to light 40 years later. By comparing the collection date and some homemade film of the actual collecting episode with his own notes and photographs, Ed Harrison, early egg collector and longtime president of the Natural History Museum's Board of Governors, was able to confirm that the illegally-taken egg was the first of two laid in the same nest in the same year. This was the first evidence that condors will lay a replacement clutch when the first egg is lost. Now "double clutching," inducing birds to lay another clutch by removing the first, is used to maximize the productivity of captive condors.

Egg collections have been especially helpful in giving conservationists an idea of where endangered species might be reintroduced. For example, egg collection data provided the whereabouts of condor nest sites that might have been overlooked. Peregrine Falcon nest sites in the Santa Monica Mountains were located from data in the Western Foundation collection and protected by the National Park Service and the Santa Monica Mountains Conservancy after the species was driven to local extinction by the effects of DDT on their ability to reproduce. The per-

egrine is now recovering throughout most of its range following the banning of DDT for domestic use in 1972, and it seems very likely that it may soon reoccupy the cliffs preserved for it over the years of its absence.

When I started working at the Western Foundation in 1968, one of my first jobs was to unpack the egg collection of Alphonse and Antonin Jay, brothers who were avid collectors in the San Fernando Valley and along the Los Angeles and San Gabriel Rivers between 1890 and 1910. Their eggs were neatly rolled in cotton and stuffed tightly into tubes of newspaper with 1920 datelines. Naturally, the job went slowly because of the irresistible temptation to read the scraps of newspapers as I unrolled them. Nevertheless, I could not help but be struck by the bird life encountered by the Jay brothers compared with the present-day situation in the same areas. Here was set after set of such species as Wilson's Warbler, Willow Thrush, Yellow-billed Cuckoo, and Traill's Flycatcher, all of which became locally extinct or extremely scarce as the rich riparian habitats of our major rivers were converted into concrete channels. The Jay collection, ignored for 48 years and nearly discarded, may turn out to be critical in documenting former avian populations along the Los Angeles River as the proposal to turn the area into a greenbelt gains momentum. The collection can serve as a yardstick against which to measure progress at restoration.

In some cases, egg collections provide useful negative data. For example, ornithologists assumed for years that Golden Eagles had nested throughout the Appalachians sometime in the distant past, a dogma that led to some expensive reintroduction programs for the species. Yet an intensive search of the largest egg collections in North America showed neither a single clutch nor any written account of Golden Eagle eggs taken south of Canada and east of the Mississippi River. Surely the efficient collectors of the 19th century would have gathered such a treasure, if possible, and it would have found its way into the oological literature as it did in California, where the eggs were greatly prized even though they were relatively common.

This was especially true in San Diego County, where over 400 clutches of eagle eggs were known to have been taken between 1890 and 1960. In the late 1970s, most of the 50 or so historical Golden Eagle territories (mapped out from the Western Foundation archives by Tom Scott, a San Diego University graduate student) were still occupied by the birds. Yet following the last decade of human population growth in San Diego County, one shudders to think of the findings of the next eagle survey there.

In recent years, regional breeding bird atlases have come into vogue throughout America; such volumes are in progress for more than 20 states. Egg

collections have been some of the main sources of data for most of these states. Comparison of historical data with current knowledge often reveals striking changes in bird distribution.

Some historians have even consulted our collections to track the collectors themselves. C. Stuart Houston and Marc Bechard have produced biographical accounts of the oologists of the northern Great Plains states and the Prairie Provinces of Canada using data slips and correspondence from the Western Foundation and other institutions. Another historian reconstructed the collecting itinerary of the important Texas collector A.J.B. Kirn, whose own data slips, field notes, and correspondence were accidentally burned by a janitor at the small college where his eggs were housed.

Many changes in bird distribution result not from catastrophic events, but from gradual environmental change. Risto Väisänen, a Finnish geneticist, examined trends in Ringed Plover egg size in Scandinavia and the British Isles over the last century as a result of climatic changes. As in most species, its egg size is closely correlated with body size. Väisänen's measurements of over 1,000 museum egg sets of this common shorebird revealed that 100 years ago, there were three size morphs of the species in existence. One was small-bodied (as indicated by egg size), bred late in the season, and occurred in the northern part of the breeding range. Another was large, bred late in the season, and occurred in the southern portion of the breeding range. Their ranges did not overlap, and they were probably distinct subspecies. A third size morph, intermediate between the large and small populations, was characterized by medium-sized eggs and breeding on average 15 days earlier than the other two, and occurred throughout the range of the species. During the last 120 years, the European climate has gotten progressively warmer. In this period, the medium-sized plovers have increased greatly in numbers, most likely because their tendency to breed earlier has given them a competitive advantage over the later-breeding types of the colder epoch. If the climate continues to warm, the populations of large and small plovers may be completely replaced by the better adapted medium-sized birds.

Biologist Fred Schaffner is using bird eggs to document a different environmental change. Fresh water and seawater have different proportions of the two stable oxygen isotopes. The differences show up in the organisms living in these environments and also in the eggshells of the birds that eat them. Thus, eggshells may provide an index to salinity at particular times and places. Comparing Western Foundation eggs taken in the Florida Everglades in the last



Frans Lanting/Minden Pictures

A cameo scene carved into an emu eggshell. Such creations were formerly sold as tourist items in Australia.

A normal Brown Pelican egg and a 1969 thin-shelled specimen, which was crushed by the weight of the incubating mother. Thinning was caused by the contaminant DDE.



Clark Sumida

century with recent specimens, Schaffner is attempting to determine whether more fresh water flowed through the swamp before the construction of Florida's elaborate canal system. His findings may well influence future management policy in this ecologically fragile area.

The most dramatic environmental changes occurring within the modern era have been the result of the intrusion of environmental contaminants, especially synthetic chemicals, into even the world's most remote ecosystems. Egg specimens have played a critical role in documenting the extent and effects of some of these pollutants, and eggshells continue to serve as one of their principal monitoring tools.

Like many profound scientific discoveries, the confirmation that DDT was harmful came from several different quarters at the same time. British researcher Derek Ratcliffe was the first to report that the widespread breeding failures of several species of British birds of prey, especially the peregrine falcon, were due to a drastic reduction of their eggshell weight and resulting breakage. On this continent, Daniel Anderson, under the direction of University of Wisconsin professor Joseph Hickey, visited over 50 private and institutional egg collections and measured the actual thickness of 34,000 museum eggshells of various North American birds. He found a significant decrease in thickness, in many cases more than 20%, in recent years in many fish- and bird-eating species.

Meanwhile, on this coast, Robert DeLong and the late Ralph Schreiber reported that traditional Brown Pelican colonies on Anacapa Island and the Los Coronados Islands had suffered virtually complete breeding failure during the 1967 and 1968 breeding seasons, possibly because of some contaminant. It was found that the pelicans, like the British raptors, were laying eggs with extremely thin shells, which were crushed by the weight of the incubating parent soon after laying. Analyses revealed very high

levels of DDE, a breakdown metabolite of DDT, in the yolks. Laboratory experiments confirmed that this compound readily caused eggshell thinning in several species of birds. Further evidence against DDT accumulated rapidly from both laboratory and field studies, and a now landmark series of hearings was held in Wisconsin in 1971 to consider public policy regarding the ubiquitous pesticide. Both crushed pelican eggs and normal specimens from the Western Foundation were introduced as evidence, and eventually DDT was banned in Wisconsin. In 1972, the Environmental Protection Agency banned domestic use of DDT throughout the U.S., following the lead of various European countries, the U.S.S.R., and Canada.

Despite the EPA decision, proponents of DDT still scoffed at the notion that the pesticide was harmful. They argued that thin eggshells, which occurred only a year after the general introduction of DDT in 1947, could not have been caused by the pesticide so quickly after its application. After all, an effect could not precede its purported cause: it would have been impossible for the contaminant to work its way up the food chain to peregrines between the 1947 introduction of DDT and the first thin eggshells in the 1948 breeding season. In an elegant and lethal response to this criticism, David Peakall, a British biochemist, injected 1948 California peregrine falcon eggs from the Western Foundation with ether to extract the fat content from the eggshell membranes still present in the museum specimens. His prediction that the extract would contain lipid soluble organochlorine contaminants, including DDE, proved true. In fact, the amount of DDE present correlated perfectly with the amount of eggshell thinning observed in the eggs. Little was heard from the DDT lobby after Peakall's findings were published in *Science* in 1974. Although banned in most northern temperate countries nearly 20 years ago, DDT use is still permitted in most tropical regions

and has only recently begun to decline, more as the result of acquired resistance in the target pests than from ecological considerations. The Western Foundation has become an international depository for egg specimens salvaged for contaminant analysis. Collection manager Clark Sumida annually measures the thickness of thousands of eggshell fragments sent by biologists interested in monitoring eggshell quality in various bird species, including many endangered ones. Although "hot spots" of high DDE levels still remain in some areas (especially southern California, where the last U.S. DDT manufacturing plant remained active until 1982), there has been a gratifying recovery of many affected populations, including the local Brown Pelicans and Peregrine Falcons throughout much of their cosmopolitan range.

Researchers are now turning their attention to other contaminants, especially heavy metals, which show up in eggshells. For the most part, the results of these studies are too preliminary to interpret, but they have indicated some tantalizing future research directions. For example, among California Condor eggshells from central and southern California, the highest levels of lead were found in the oldest sample — fragments from a historical condor nest in rugged Eaton Canyon in the San Gabriel Mountains — more than 70 years after the nest cavity was last used. Do the high levels of this contaminant reflect lead fallout from the Los Angeles Basin, inherent characteristics of the soil in which they were found, or some artifact of lab analysis? Future research will no doubt provide an answer to these questions.

Most recently, X-ray fluorescence spectrom-

etry has shown measurable levels of calcium, barium, copper, iron, strontium, and zinc in eggshells. This technology may help monitor long-term changes in mineral cycling behavior as affected by chronic environmental pollutants, especially acid rain, on a regional scale. It is a technique that can be used without killing the birds or even taking viable eggs, since hatched eggshell fragments can be used for the analyses. I have religiously collected eggshell fragments since 1968, solely on the faith that they would somehow come in handy, and they are now being used almost as much as whole eggshells.

Human interests and cultural directions constantly change, as evidenced by attitudes toward bird eggs and oology. Through it all, museum specimens survive and take on new significance. "A museum has an obligation," wrote S. Dillon Ripley, former Secretary of the Smithsonian Institution, "to . . . prove the validity of its collections. Natural history collections serve inevitably as data banks, figures marked upon the clock face of environmental time." There is no stronger verification of this statement than that afforded by museum bird egg collections.

Lloyd Kiff is Director of the Western Foundation of Vertebrate Zoology (since 1968), president-elect of the Cooper Ornithological Society, and leader of the California Condor Recovery Team; he was Acting Curator of Ornithology at the Natural History Museum from 1988 through 1991. His research interests include various aspects of the avian egg, condors, effects of DDE on bird reproduction, and neotropical ecology. He is presently conducting research on the breeding biology of the birds of Ecuador.

Each museum egg set specimen is accompanied by a data card with collection data.

THE ECOLOGICAL COLLECTION OF

W. MAITLAND CONGREVE.

Ref. No. 22

Set Mark 450

No. in Set 16

SPECIES British Great Titmouse

Parus major nestlani

Date Collected 28. IV. 1945

Incubation embryos formed (all fertile)

Locality grounds of "Houndwood" Exley, N. Salisbury, Wiltshire

Nest & notes In one of my old nesting boxes. This one hung about 5' from ground, on trunk of a Silver Birch, in a small plantation of same, outside E. boundary of kitchen garden. Last year a fox bit nest. Taken up, highly incubated. The largest clutch ever seen (cf. J. P.).

Actual collector. W. M. Congreve

Certified by. [Signature]

COLLECTION OF WILSON C. HANNA,
141 EAST F STREET, COLTON, CALIFORNIA.

A. O. U. No. 713

Set Mark 1495

No. of Eggs 4

Locality Hesperia

Incubation:

Name Heleodytes brunneicapillus

conesi

Northern Cactus Wren

Date May 13, 1923

Identify Positive

Desert, San Bernardino Co., Calif.

3ft. from ground, conspicuous,

stems, etc. with lining of

few feathers. Large retort shaped

on side.

Diameter inside

Depth inside

57, 3.53, 3.72, 3.93

nest, Nest unusual in not

feathers in lining.

[Signature]

Clark Sumida

Huauhtli: The Mysterious Miracle Weed

by John W. Wright and Teresa Reyna Trujillo

WHAT IF SOMEONE TOLD YOU that they had discovered a new "grain" that grows vigorously; resists drought, heat and pests; produces in quantities comparable to the world's more commonly used grains (corn, wheat and rice); and surpasses all in nutritional quality, having not only a nearly complete protein with twice the amount of lysine of wheat (lysine is one of the essential amino acids that is in short supply in plants), three times as much as corn and about as much as milk? It can be eaten as a tasty

huauhtli — while not exactly a household word, has a long history of use and cultivation that began more than 7,000 years ago.

The earliest, most convincing evidence of human use of *huauhtli* came from a series of dry caves in the Tehuacan Desert of south central Mexico. There in the 1950s and 1960s, Richard MacNeish, a leading archaeologist of Mesoamerica, and his associates found dry seeds, flower parts and whole flowering stalks in direct association with human middens, and importantly, remains of seeds in human coprolites. The other agricultural products found in association with *huauhtli* included corn, squash, beans and chiles, all of which were sufficiently modified from their wild progenitors to be convincing cultivars resulting from agricultural domestication and selection. The MacNeish group identified this site and the association of four crop plants (corn, beans, squash, and *huauhtli*) as the earliest evidence of the dominant agricultural economy that had spread throughout Mesoamerica by 2000 B.C., extending as far north as the southern United States. There was a parallel domestication involving another species of *huauhtli* in the Andean region of South America, dating back at least 4,000 years. Peruvian ethnobotanist Francisco Herrera thought that *la quihuicha*, as in it known in the southern Quechuan dialect of Peru, was an important Pre-Inca crop in widespread use in the Andes before the arrival of corn from North America.

By the time Columbus arrived in the New World, *huauhtli* was a widespread and well-established crop. The earliest report of it was contained in the second letter to the King of Spain written by none less than Hernán Cortez in Mexico in 1520. This was followed by more detailed accounts in codices (books of hieroglyphs and their interpretations) and reports by such early chroniclers as Bernardino de Sahagún in 1570, Francisco Hernandez in 1575 and Juan Bautista Pomar in 1582. The prominent role played by *huauhtli* in pre-conquest Mexico and the Aztec Empire was noted by Hernando de Alvarado Tezozómoc (ca. 1598), a native historian, and was detailed in the famous codex *Matrícula de Tributos*, a list of tribute received by Moctezuma from the thirty-three provinces of his Aztec Empire. Most of the provinces were required to fill at least one granary with *huauhtli* every year and some were required to fill two. A single granary is thought to have contained some 10,000 bushels of seed, making an annual tax levy for *huauhtli* of about 200,000 bushels or some 20,000 tons. Placed into perspective by comparisons with the other items of tribute levied by Moctezuma (280,000 bushels of corn and 230,000 bushels of beans), *huauhtli* was indeed an important food crop to the Aztecs. It continued to be identified as a major crop in the Spanish royal inquiries, called *Relaciones*, that began in 1577. Most of these con-



nut-like breakfast cereal, parched or simply cooked into a gruel, porridge, pilaf or soup. It can be milled to produce a sweet, light-colored flour suitable for biscuits, breads, cakes and other baked goods. When heated dry it will pop like tiny, nutty-flavored popcorn, which is light and crisp and can be eaten as a snack, as cold cereal with milk and honey, used as a breading on meats and vegetables, or held together with honey or syrup and eaten as a sweet confection or candy. Next you would be told that the young plants can also be eaten as a vegetable that not only out-performs spinach in taste tests but has far greater nutritional value.

After all of this, you would then be told that agriculturalists around the world are in agreement that it will be THE crop for the human population in the twenty-first century, perhaps surpassing all other food crops in tons of production. But before you could find out where you could have a taste-test to get a leg up on the rest of the world, you would be told that it wasn't really discovered, but rather rediscovered. The name of this versatile crop —

Wild *huauhtli* plants against a backdrop of blue Arizona sky. The mixed sample of seeds obtained by Major John Wesley Powell during his exploration of the Grand Canyon in the 1870s from some American Indian group contained small black seeds of this weedy species as well as pale seeds of a cultivated species. The seeds of both were germinated and the resulting plants were described as new species. The wild one (a common weed in our Southwest) was named in honor of Major Powell. Photo by the author.

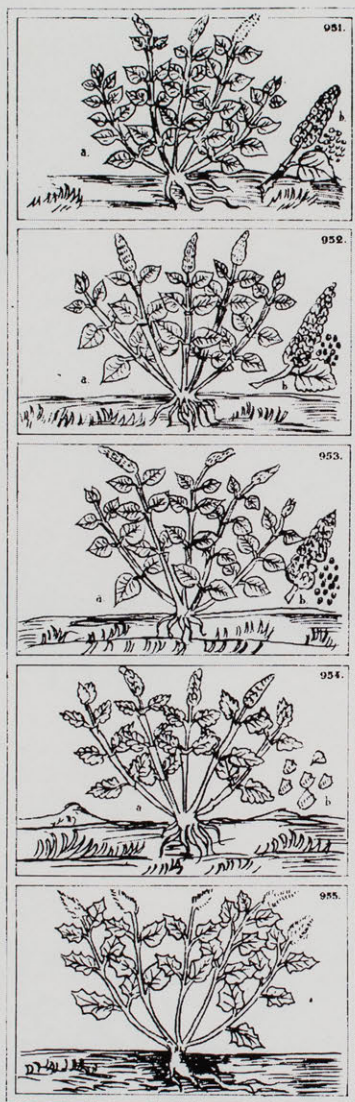
OPPOSITE ►

The relatively large, pale seeds of the cultivated *huauhtli* resulting from early selection from their tiny, black-seeded ancestors over some 7,000 years of domestication. Modern cultivars of *huauhtli* produce seeds varying in color from white through pinks and reds to black. Photo courtesy of the Rodale Institute, Kutztown, Pennsylvania.



Diagrammatic illustrations of some of the eight *huauhtli* described by Fray Bernardino de Sahagún in his 1577

Florentine Codex. While not truly diagnostic, the shapes of the leaves, flowering heads, and seeds allow for the allocation of the illustrations to existing species and their pre-Conquest names and uses.



The estimated distribution of the cultivation of *huauhtli* at the time of European contact. The small area in northern Arizona marked with "?" represents the supposed location of the cultivated *huauhtli* obtained by the Powell Grand Canyon Expedition of the 1870s. This species has never been rediscovered in the United States. After J. Sauer, 1950.

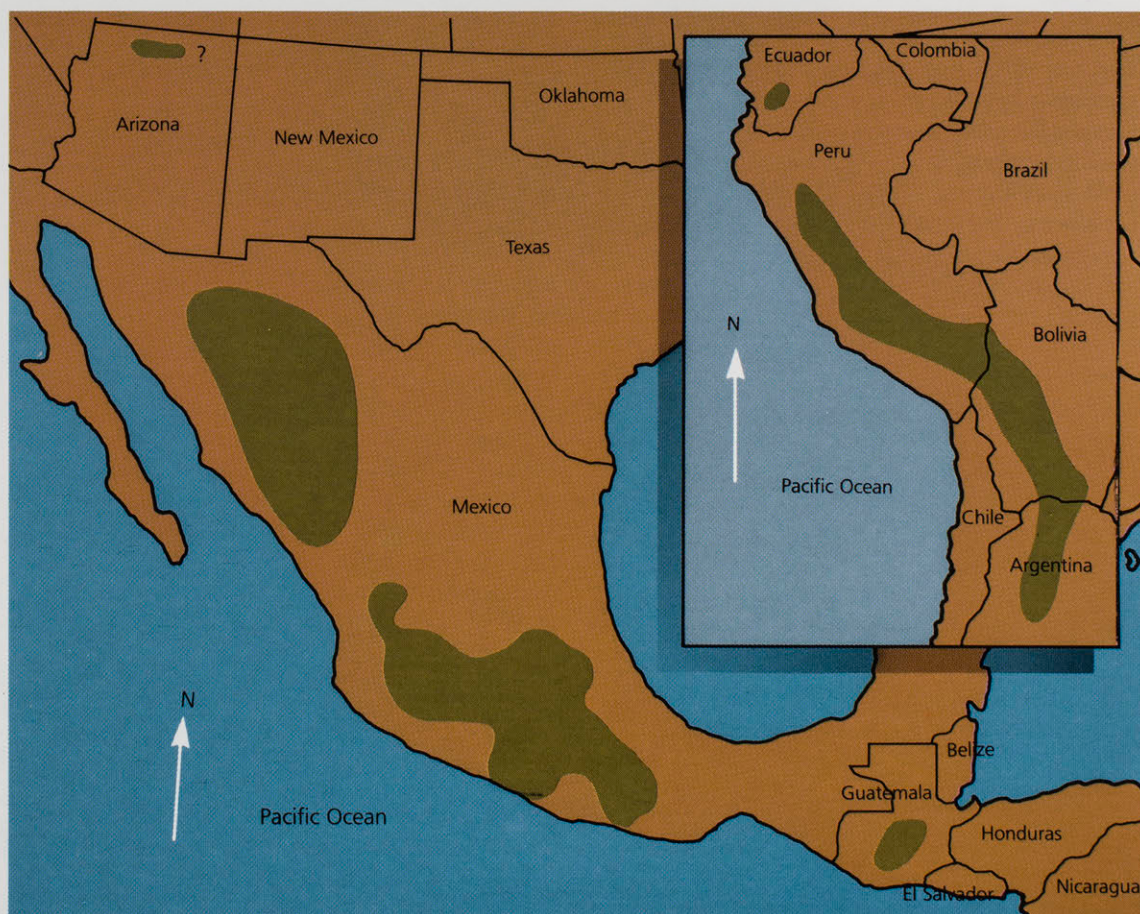
firmed the importance of the crop within the old Aztec tribute area and provided descriptions of the principal ways it was prepared and eaten.

We will return to the early history of *huauhtli*, but now we should jump forward some three hundred years to 1845. This is the year that American ethnologist A. Gallatin, an early Mesoamerican anthropologist, published his *Notes on the Semi-civilized Nations of Mexico, Yucatan, and Central America*, in which he wrote "I cannot discover what is meant by *guatli* [*huauhtli*, also spelled *huautli* and *oauhtli*]. It is interpreted as being *semilla de bleo* [seeds of *blitum*], but I am not aware of any other grain than maize having been an article of food of such general use, as the quantity mentioned seems to indicate." In the 1880's the Mexican government distributed an agricultural questionnaire, similar to the royal *Relaciones* three centuries earlier, that requested information on local crops. Although the resulting list was extensive, there was not a single mention of *huauhtli* even from the same pueblos and provinces identified as the major contributors of imperial tribute. Astounding! So, what was *huauhtli* and what happened to it?

Before we can answer these questions we need to look at what the early chroniclers wrote about *huauhtli*. Cortez informed his king that the Aztecs used various seeds called *huauhtli* and that these

seeds were milled and kneaded with the blood of human sacrifices into a paste called *zoale* or *tzoalli* that was used to make heathen idols. These idols were then eaten during religious rituals honoring their many gods. A detailed description of one of these ceremonies is contained in the Ramirez Codex of about 1550. It describes the May ceremony honoring Huitzilopochtli, the War God, that was celebrated throughout the Aztec empire. The principal ceremony took place at the Temple Pyramid in Tenochtitlan, the Aztec capital in central present-day Mexico City. The entire populace of the city, in full ceremonial costumes, attended the festival. They were treated with music, dancing and an abundance of human sacrifices. The main event was the parading of a huge idol made of *zoale* and shaped in the form of Huitzilopochtli. This idol was carried throughout the capital on a litter. At the close of the ceremony, the idol was broken into small pieces and ritually eaten by the populace. It was further noted that no food other than *zoale* could be eaten in the Empire during the festival day. Curiously, while *zoale* and a soup of *zoale* were fed to the sacrificial slaves, there is no indication that any of the *zoale* was made with human blood. Rather, it was said to have been made of dough and honey.

The most extensive, and probably most accu-



rate, accounts of the ritual use of *huauhtli* in ceremonial idols was provided by the Franciscan historian Sahagún. He described numerous regular and irregular ceremonies honoring a variety of gods; all involved the ritual construction of *zoale* idols and their subsequent consumption by the participants. Again, Sahagún made no mention of *zoale* made from human blood, only honey.

With or without blood, the ceremonial use of *huauhtli* to make idols apparently was so alarmingly similar to the Christian communion practiced by the colonial Spaniards that it was viewed as an especially offensive form of idolatry. This led to an all-out effort by the church and all good Christians, meaning all the King's men, to eradicate this pagan idolatry. The result was the near elimination not only of *zoale* but of the use of *huauhtli* itself. Even as late as 1656 one priest noted that the continued use of *zoale* in the Valley of Mexico was revealed in "confessions of certain delinquents." As noted above, by 1845, even the identity of *huauhtli* had been lost, and it remained lost until the middle of this century. Today, most Mexicans with some familiarity with Nahuatl, the language of the Aztecs, would define *huauhtli* as "fish or insect eggs," and not as "grain" consumed in enormous quantities, sometimes under very special circumstances, by their predecessors.

The ultimate identity of *huauhtli* was made especially difficult, because it was clear early on that it was more than one thing. For example, Sahagún listed some nine kinds or forms of *huauhtli*. He used prefixes such as *xochi* (flower), *nex* (ash), *tlapal* (red) and *michi* (fish) in combination with the word *huauhtli* as names for the various kinds and forms.

In the late 1900's and the beginning of this century, interest in identifying *huauhtli* was the center of considerable debate. Some speculated that it might have been one or more small varieties of maize (corn), grain from another cereal grass called "wheat of Michoacán" or even the pollen of tulle. It remained for Jonathan Sauer, now Professor Emeritus at the University of California at Los Angeles to put the speculation to rest. His study is a truly outstanding example of scholarship, combining methodologies from a variety of scientific disciplines (botany, ethnology, linguistics, history) and extensive fieldwork. His master opus was published in 1950 under the title of *The Grain Amaranths: A survey of Their History and Classification*.

The "grain" we have been talking about is amaranth, the international common name for members of the plant genus *Amaranthus*, a group of some 60 species, three of which have had long histories of



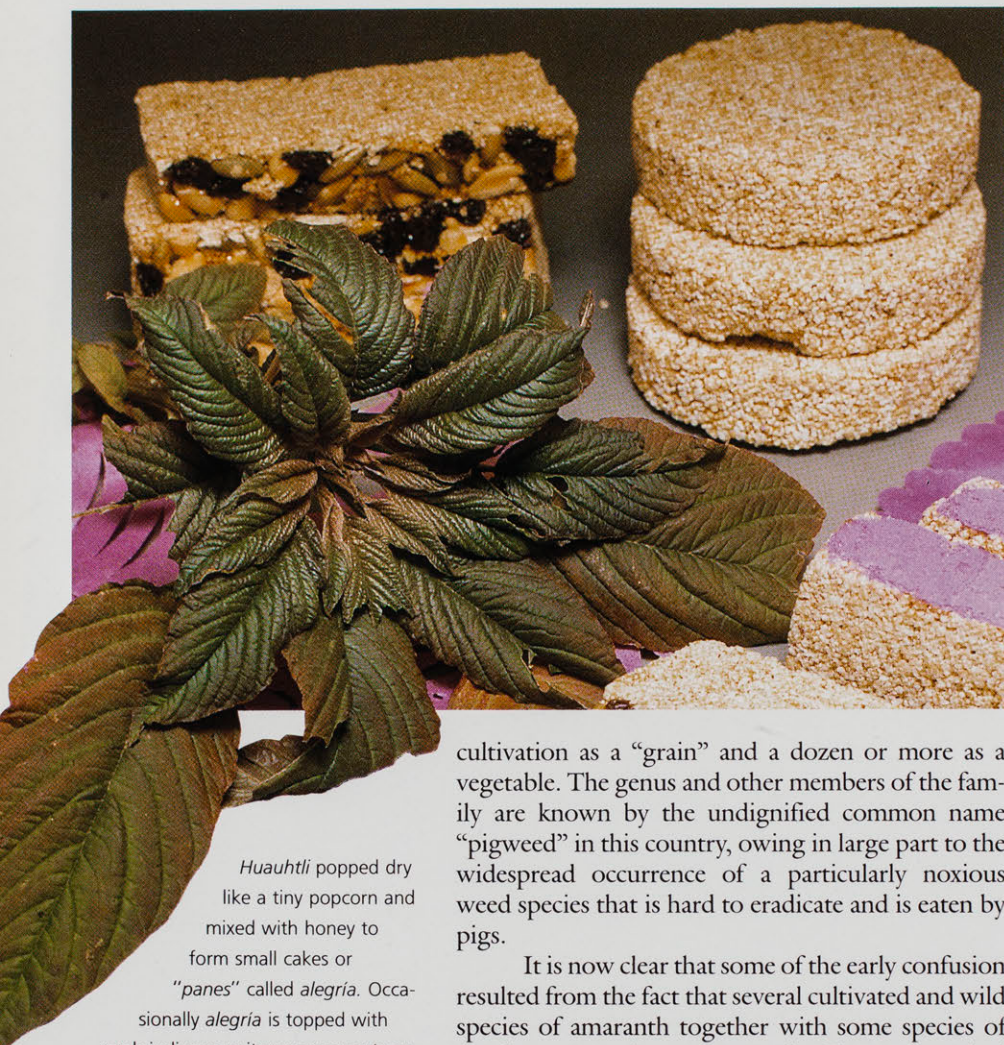
A "page" from the *Matricula de Tributos* or *Codex de Moctezuma*. This ancient hieroglyphic document details the tribute or taxes levied on the 33 provinces by Moctezuma, the Aztec Emperor. This book was written at about the time that Hernán Cortez entered the city of Tenochtitlan in 1521. The script writing in both Nahuatl and Spanish was added later.

This page details the tribute required from the province of Ocuilan. Today this area lies southwest of Mexico City immediately west of Cuernavaca.

The codex is read from bottom to top, with the six symbols at the bottom representing the tribute-collecting towns in the province. The next series are

mantas (cap or blankets) of four different patterns. The featherlike symbol represents 400; thus 1600 *mantas* were required every 80 days. Next are two costumes and shields. The first, the yellow warrior costume, was required once a year. Twenty of the second costume, the blue warrior, were required annually.

The next line, of five sack-like figures each with the 400 "plume" above, represents 2,000 bags of salt. The uppermost figures are bins containing beans, corn, and *huauhtli*, and indicate that two bins of each were required. Most of the provinces were required to contribute *huauhtli*, with the annual tribute totalling some 20,000 tons.



Huauhtli popped dry like a tiny popcorn and mixed with honey to form small cakes or "panes" called *alegría*. Occasionally *alegría* is topped with such indigenous items as peanuts or squash or pumpkin seeds, or dried fruits such as raisins. *Zoale* was made primarily from milled huauhtli and shaped into the form of gods and then eaten in communion-like ceremonies by the Aztecs in the worship of their many deities. This practice apparently was so appalling to the colonial Spaniards that the making of *zoale* was actively discouraged throughout Mexico and the identity and growing of huauhtli was nearly lost. Photo courtesy of Arq. Jorge O. Hernandez N.

cultivation as a "grain" and a dozen or more as a vegetable. The genus and other members of the family are known by the undignified common name "pigweed" in this country, owing in large part to the widespread occurrence of a particularly noxious weed species that is hard to eradicate and is eaten by pigs.

It is now clear that some of the early confusion resulted from the fact that several cultivated and wild species of amaranth together with some species of another genus of common weeds, *Chenopodium*, had been variously grouped under the name *huauhtli* by both early chroniclers and the Aztecs themselves. *Zoale*, on the other hand, appears to have had a more restrictive meaning — "pastries" — and was made primarily with the large pale seeds of the cultivated species. The black seeds from the wild species were painstakingly removed before popping or milling.

Several lines of evidence suggest prehispanic cultivation of amaranth as a grain in or near our own Southwest. Caches of seed have been recovered from prehispanic archaeological sites in Arizona and Arkansas and from human coprolites (dating from 300 to 1100 B.C.) from a cave in Kentucky, but these seeds are small and black and were probably gathered from wild, or at most tended, rather than cultivated, plants. The earliest written account for the use of amaranth in the region was provided by Alvar Núñez Cabeza de Vaca in 1555. His observations were made during his epic trek through northern Mexico and our Southwest. He wrote that "the coast has no maize and they eat powder of blede and of straw and of fish." It is thought likely that Núñez observed the non-agricultural Seri Indians along the coast of So-

nora, and if so, it is also likely that the seeds he saw them using were small, black, and gathered from a wild species in much the same fashion as the modern O'O'Dam (the preferred tribal name for the Papago) of northern Sonora and southern Arizona gather amaranth today. Their methods of gathering and usage is described in some detail by Gary Nabhan in his award-winning book *Gathering the Desert*. Again, while the O'O'Dam may provide some care for the plants, the seeds produced and gathered are small and black and from species other than the three "domestic" species. A group related to the O'O'Dam, the Jovas, a now completely assimilated Rancheria Piman group from the Sahuaripa-Bacanora region of central Sonora, were cultivating pale-seeded *huauhtli* in the 1760's, as were at least some Tarahumares, an unrelated group in the mountains to the east, in the 1770s.

Another line of evidence for actual cultivation is more convincing, but is shrouded in mystery. Major John Wesley Powell, of Colorado River and Grand Canyon exploration fame, sent a small, mixed sample of seeds to Sereno Watson, a botanist at Harvard University. The seeds were apparently obtained in the 1870s from some indigenous group in Arizona. Watson planted the seeds in a greenhouse, grew the plants, prepared scientific herbarium specimens and named the plants resulting as two new species. The species grown from the small, dark seeds he named *Amaranthus powellii*. The common wild species of amaranth in the Great Basin and Northern Arizona stills bears this name. The species grown from larger, pale seeds he called *Amaranthus leucocarpus*. Subsequently, this species was found to be similar but not identical to the widespread cultivated species in Mexico, and Watson's name was used for the entire cultivated species.

However, *leucocarpus* has never been found again in Arizona or elsewhere in the United States. Furthermore, it is not clear who gave the seeds to Powell, as the Powell Expeditions contacted several indigenous groups. Most of these contacts were hostile; one led to the deaths of three of Powell's crew members. It is thought by some that the Paiute, a group which occupied the north side of the Grand Canyon in Powell's time, may have cultivated amaranth; this idea perhaps stems from Powell's discovery. Traditionally, the Paiute were semi-nomadic hunters and gatherers who for the most part learned to farm from Mormon settlers farther to the north. *Huauhtli*, however, was never a Mormon crop, and the Shivwits Paiutes in the 1870's were hostile even to the Mormons. In the absence of hard evidence, it seems more likely that Powell would have secured the seeds from one of the agricultural Pai groups (Havasupai or Hualapai) who still farm the south side of the Grand Canyon. These groups were some of the last to receive contact from Europeans and had long

been confused with other tribal groups, which could account for the lack of precision in identifying the seed donor. Interestingly, though, there is no evidence that any of the Pai groups ever cultivated a domesticated species of amaranth. It remains a mystery, but it is certain that the cultivation of *huauhtli* in this country — and perhaps even the cultivators — have gone extinct.

Sometime early in the Conquest Period of Mexico, grain amaranth was carried to Asia. There it met with a great reception and became a popular crop in India, Pakistan, Nepal, and China. Some of the dry hill country in India has been described as “on fire” with the red and yellow patches of color represented by fields of amaranth. Over much of northern India it is grown in more than half of the non-irrigated cropland. In Southern India it is reported to be so popular that it has been given names like *raigira* (king seed) and *ramdana* (seed sent by God), and as perhaps a *deja vu*, it is eaten on festival days when the eating of other grains is forbidden.

Huauhtli also made its way to Europe from the New World and from Asia. One specimen fell into the hands of Carolus Linneaus in Sweden and was described as *Amaranthus hypocondriacus* in 1753. Up to 1967 this name was used for a common species known from Asia, especially China. Dr. Sauer determined that Linneaus’ species is the same as Watson’s mysterious *leucocarpus*. Now the most common species of grain amaranth, first domesticated in Mexico thousands of years ago, is known under the name of *Amaranthus hypochondriacus*. Thus by the vagaries of botanical nomenclature we have lost the threads of historical nomenclatorial connection of amaranth to Mexico, to the Aztecs, and to their ancestors who first cultivated *huauhtli*. We have lost as well the connection to the mystery surrounding Watson’s *Amaranthus leucocarpus*.

In Mexico, meanwhile, *huauhtli* became an “underground” crop. It continued to be grown in small garden plots and in more remote, less Hispanized villages throughout the country. *Zoale* (amaranth and honey) initially suffered the same fate, but at some point it underwent a name change in urban areas to *alegría*. This is now a commonly produced and widely sold confection made of popped amaranth and honey known by virtually everyone living around the former Aztec capital in the Valley of Mexico (some 22 million people). Interestingly, *alegría* is Spanish for “happiness,” and when plural it means “public festivals or rejoicings.” Jonathan Sauer has noted that there seems to be a larger number of *alegría* vendors around churches and festivals, and that both the vendors and the quantity of *alegría* appear to increase around certain holy days. While he offered no explanation for this observation, it is improbable but intriguing to think that *zoale* still lives in the hearts of the Chilangos (the modern descen-

dants of the Aztecs) and that *alegría* represents a symbol of subtle continuing resistance to the Conquistadors from Spain and their church.

Dr. John W. Wright is Curator and Head of Herpetology at the Natural History Museum, where he is responsible for the collections of amphibians and reptiles. His research interests are wide-ranging and include ethnobiology, a subject he has found fascinating since his undergraduate days as an anthropology major at the University of New Mexico.

Dra. Teresa Reyna Trujillo is a Professor in the Instituto de Geografía at the Universidad Nacional Autónoma de México (UNAM). Her special interest is in climatology, especially the geographical distribution of microclimates suitable for the cultivation of “new crops” such as *huauhtli*. The collaborative relationship that produced this article had a herpetological root as Dra. Reyna’s spouse is a herpetologist at UNAM and a Research Associate in Herpetology at the Natural History Museum.

Drs. Reyna and Wright are completing a sequel to this article focusing on the special attributes of *huauhtli* as a plant and as a “grain,” including the prehispanic and modern methods of preparing it as food.

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The tall *huauhtli* plants bearing large, colorful inflorescences that produce literally hundreds of thousands of pale seeds, called “grain.” While not truly a grain, they so resemble it in appearance and usage that the term has been used since colonial times. Photo courtesy of the Rodale Institute, Kutztown, Pennsylvania.

Stars of the Florida Keys

by Gordon Hendler

OPPOSITE ►

As a result of its epidermis, generously endowed with mucus glands, and a dense underlying cushion of connective tissue, the body of this colorful *Ophiomyxa flaccida* is unmistakably slick and soft to the touch; hence its scientific name, liberally translated as "soft mucus snake." However its connective tissue cushion has the capacity to stiffen, providing a protective shield when the brittlestar is threatened.

Here, two brittlestar arm tips hurriedly wave goodbye from the mouth of a Spanish hogfish. Had the fish been less successful and missed part of its prey's disc and arms, the surviving piece of brittlestar could have healed and regenerated. Over 30 species of Caribbean reef fishes are known to feed on brittlestars.

"On the flats and reefs, near islands and keys, may be found colonies of Ophiothrix, blue, green or red, with their translucent thorny arm spines, and the humble Ophiactis swarming on great sponges; while here and there a yellow or vermilion star marks the soft Ophiomyxa flaccida. To the brown gorgonians clings the large Ophiocoma, similar in color; and sometimes a Medusa-head, whose branching arms excited the wonder of old Rondelet, twine about their thicker stems, these and their companions, living in a strong light, and in warm shallow water, present brilliant and well-marked colors." (A. Agassiz, "Three Cruises of the . . . Blake", 1888)

MY INTRODUCTION TO THE BRITTLESTARS OF THE Florida Keys dates back to the antediluvian 1960's but the experience is still fresh in my mind. It involved an airplane trip, my first ever, from my university in Connecticut to Florida. This auspicious pilgrimage grew out of my doctoral degree project. In part, it was to be a collecting trip, in part a chance to meet the world's foremost brittlestar guru. My mentor-to-be, Lowell P. Thomas, (not the famous newscaster of the same name) was a professor at the University of Miami. Not long after I met him, Lowell metamorphosed from a zoologist to a psychologist, and migrated north. But before his mid-life career adjustment, he was kind enough to take me snorkeling at French and Molasses Reefs, off Key Largo. That day on the reef resulted in the worst sunburn I have ever had; my pallid back turned red, and the blisters peeled off in sheets. But the expedition also provided my first enchanting glimpse of a lemon-yellow, smooth-skinned *Ophiomyxa*, the same species that had impressed Alexander Agassiz (1835-1910), the famous copper magnate, philanthropist, authority on the sea urchins, and curator at the Harvard University Museum founded by his father, Louis Agassiz.





OPPOSITE ►

Ophioderma cinereum is one of the most abundant shallow-water brittlestars. Individuals on coral reefs are often a pale gray, and those living in muddy mangrove habitats a chocolate color. The pairs of dark-bordered plates at the base of each of the arms — looking something like almonds embedded in a cookie — are helpful for field identification of this species. Large individuals like these have discs an inch or more in diameter, and arms at least 6 inches long.

BELOW

Instead of the usual five simple brittlestar appendages, *Astrophyton muricatum*, a basketstar, has intricately arborescent arms. Often mistaken for plants, these brittlestars hide during the day and crawl to the top of the same exposed perch every night. A large specimen may be a yard across with its arms unfurled, and have 10,000 threadlike arm branches, each bearing hundreds of microscopic hooks used to secure its tiny planktonic prey.

Lowell also gave me a bit of advice that boiled down to “if you want to know what that brittlestar is, figure it out for yourself.” These many years later, I am still following Lowell’s words of wisdom. They have led me to make numerous trips to the Keys and other venues where brittlestars abound, and recently culminated in co-authoring a book on the echinoderms of the Florida Keys and Bahama Islands, a project now in its last stages. In a way, this article is an introduction to that book and to the fascinations of brittlestar biology. Like many passionate affairs, my scientific infatuation evolved from a delight with corporeal beauty — something that brittlestars truly possess, as the pictures on these pages attest.

Brittlestars belong to the phylum Echinodermata, a familiar group of marine animals that also includes starfishes, sea urchins, sea cucumbers, and feather stars. Nearly all of them have a spiny calcite skeleton, but the group exhibits a fantastic variety of body shapes. The Danes, who have produced some of the world’s foremost students of echinoderm biology, invented a common name for the echinoderms: *Pighude*, meaning “spiny skins” — not a mellifluous candidate as an English cognate term. English-speaking enthusiasts of these animals are saddled with the longer Greek-derived name, “echinoderms,” which has the same meaning as *Pighude* but luckily lacks even the hint of a porcine syllable.

The brittlestars owe their name to their notorious capability for voluntarily breaking their arms. This seemingly self-defeating reflex is actually an advantage for a five-armed animal clamped in the jaws

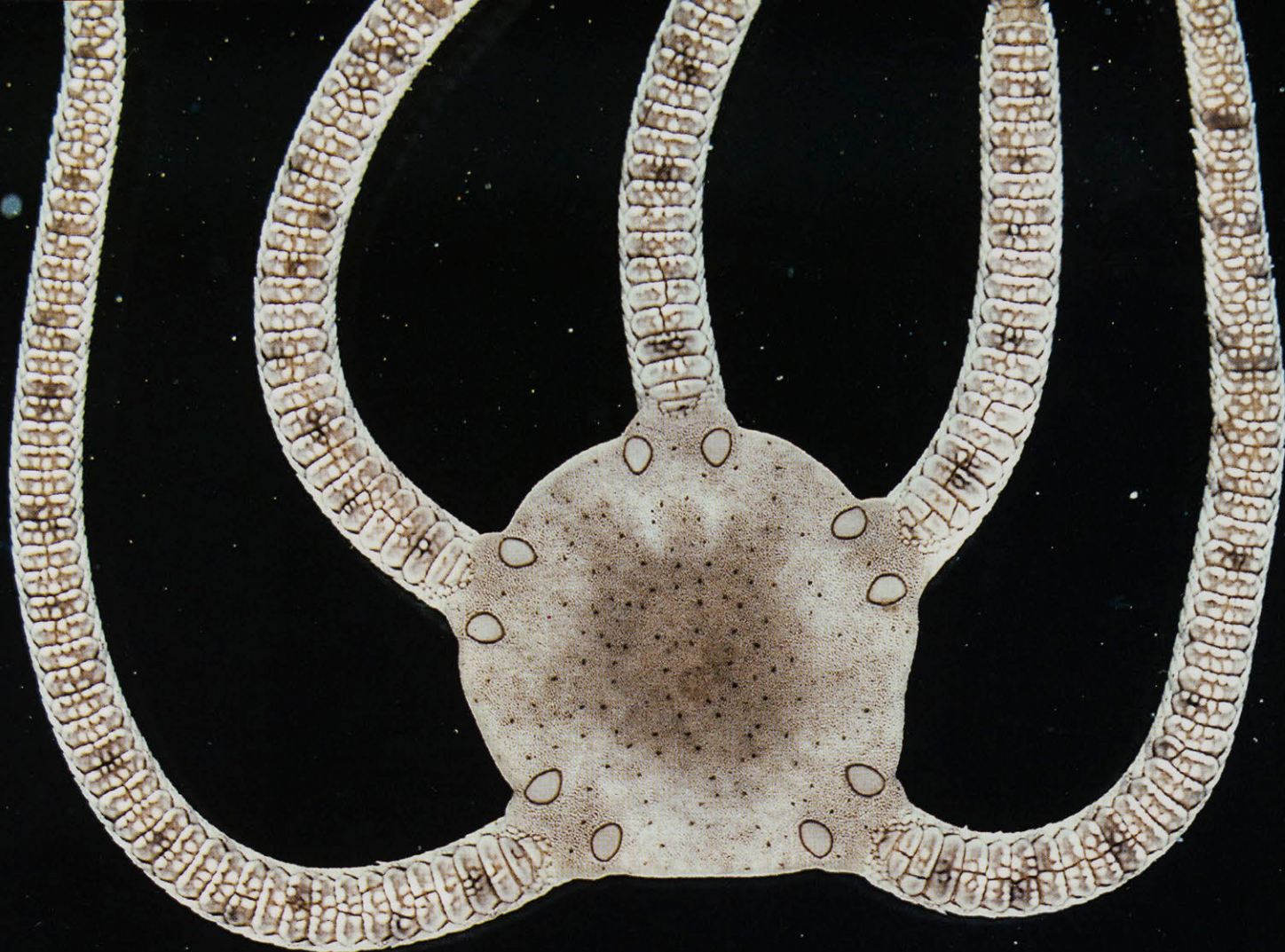
of a hungry fish — a common predicament for brittlestars. For some specialized brittlestar species, this talent for defensive self-mutilation extends to an ability to cast off the disc, the roughly circular body region to which the arms attach. It thereby also discards the stomach, gonads, and other vital organs enclosed within the disc. That process is all the more remarkable because these truncated individuals are able to completely regenerate the broken arms and regrow the disc and associated viscera.

Brittlestars from the Florida Keys debuted in the scientific literature thanks to the collecting efforts of Titian Ramsey Peale, son of the American portrait painter of the Federalist period, Charles Willson Peale. Titian, a collector and illustrator, was a contributor to the nation’s first natural history museum, originated by the elder Peale in Philadelphia in 1786. On Titian’s second journey to Florida, an ornithological jaunt in 1824, he collected some marine specimens for his friend Thomas Say, the Philadelphia naturalist. The next year, Say described six new species of brittlestars, and also became the first scientist to study a basketstar from Florida. Say’s paper, read before the prestigious Boston Society of Natural History, was entitled “On the species of the Linnaean genus *ASTERIAS*, inhabiting the coast of the United States.”

Despite that title, Thomas Say had the good judgement to assign the five-armed brittlestars in his collection, and the branching-armed basketstar, to two separate genera (“genera” is the plural of “genus”) distinct from what was then called *Asterias*. In Say’s time, over 150 years ago, the distinction between starfish and their more agile and attractive brittlestar relatives was unclear. Today, each group is accorded status as an independent, major class of invertebrates, and only a circumscribed group of starfish are referred to the genus *Asterias*. Of brittlestars alone, more than 2,000 species belonging to over 200 genera have been recognized, many of them from the Florida Keys.

Say, whose interests literally covered the waterfront — and beyond — devoted little more attention to the echinoderms during his career. Much of the remainder of his life was spent as Superintendent of Literature, Science and Education in the utopian commune of New Harmony, Indiana. It was not until the latter half of the nineteenth century that other Americans, such as Addison Emory Verrill at Yale University and Theodore Lyman at Harvard University, reinvigorated the study of brittlestars. Until then, the description and classification of brittlestars and their relatives was relinquished to distinguished European biologists. The Danish biologist Christian F. Lütken figured prominently in describing the common brittlestars from the Carib-







David Meyer

bean region, and set stringent new standards for accuracy in that endeavor. His desire for echinoderms was satisfied by a coterie of amateur naturalists in the Danish West Indies. They enthusiastically provided the specimens on which Lütken, living in Copenhagen, based his careful descriptions of species, some of which had already been described by Say. In Lütken's estimation, Say's brief descriptions were unreliably crude (probably a fair judgement).

Just as in the last century, brittlestars comprise a significant but often overlooked presence in the Keys and other tropical habitats. A recent ecological survey of the Keys found that, after stony and soft corals, brittlestars "are perhaps the most abundant and characteristic macro-invertebrate of Florida coral reefs". In Florida, they commonly throng together in densities of 40 individuals per square meter, and their numbers living in soft sediment and in algae are at least an order of magnitude higher. In the Keys, if the myriad reef ramparts and superstructure were to magically disappear, there would still be a substantial network of brittlestars left behind, arm-tip to arm-tip in many places.

H.L. Clark, echinologist extraordinaire and curator at Harvard University's Museum of Comparative Zoology, wrote about 70 years ago that "on a reef where conditions are moderately favorable, one may be reasonably sure of finding, anywhere in the West Indies, at least 15 species of brittlestar and, on an exceptionally good ground, such as Buccoo Reef, Tobago, the number may rise to 25." However, since Clark's heyday the use of SCUBA has substantially enriched our appreciation of the shallow water fauna. Around a single mangrove cay on the Belize Barrier Reef, I have collected 44 species of brittlestars by diving. A 1984-86 survey of Looe Key, Florida alone revealed 37 brittlestar species. That is a good sampling, but it is less than half the number that would be expected in SCUBA depths from an exhaustive survey the more extensive, neighboring Caribbean region. Many of those species of Florida and the Caribbean are widely distributed, and readily recognized, and new species are still being discovered.

Claims have been made that one or another brittlestar species is characteristic and predictably abundant on Caribbean reefs in general, or in specific reef zones. However, such rules are invariably broken. For example, *Ophioderma cinereum* is one of the most common shallow water coral reef brittlestars in Panama, but it is relatively rare in Belize. Scientists have stated that *Ophiocoma wendtii* or *Ophiocoma echinata* is the most abundant Caribbean brittlestar — but that distinction varies among species according to time and location. This seeming unpredictability may reflect the vagaries of successful



◀ TOP, PAGES 30 and 31

Ophiactis savignyi, arguably the most abundant brittlestar in the world, is widely distributed in tropical waters around the globe. The compact size of this species, and its ability to live in the "fouling communities" that grow on places such as ships' bottoms and flotsam, may account for its extraordinary capacity for dispersal. Small individuals such as the one opposite usually have three larger and three smaller arms, evidence that they have recently split in half and are reproducing asexually by regenerating part of the disc and several new arms. When it regrows a full complement of appendages, this brittlestar may divide again to clone another set of twins, or opt instead to grow large enough to reproduce sexually. The individual here, with arms almost an inch long, has reached such a size, but still has the telltale sextet of arms that typify asexual reproduction. The enormous numbers of this species — often hundreds or thousands of individuals pack the insides of small living sponges — attest to the frequency and success of its mode of asexual reproduction.

brittlestar reproduction and infrequent survival of young individuals. The element of uncertainty is not surprising in creatures that are at the mercy of erratic winds and waves for their dispersal.

In that regard, something should be said about the sex life of brittlestars (such as it is). Their gonads (testes and ovaries) consist of clusters of gamete-lined tubules which are housed within the disc. Individuals of most species are male or female, but they may take little relish in having a gender; fertilization is an external and seemingly impersonal affair. Spawning brittlestars assume a push-up posture, raising their discs off the bottom while pumping out a stream of gametes. Since animals standing on "tip toes," spewing tasty gametes, must be attractive and susceptible to predators, it is no wonder that brittlestars tend to spawn at night, when predation is reduced or less effective.

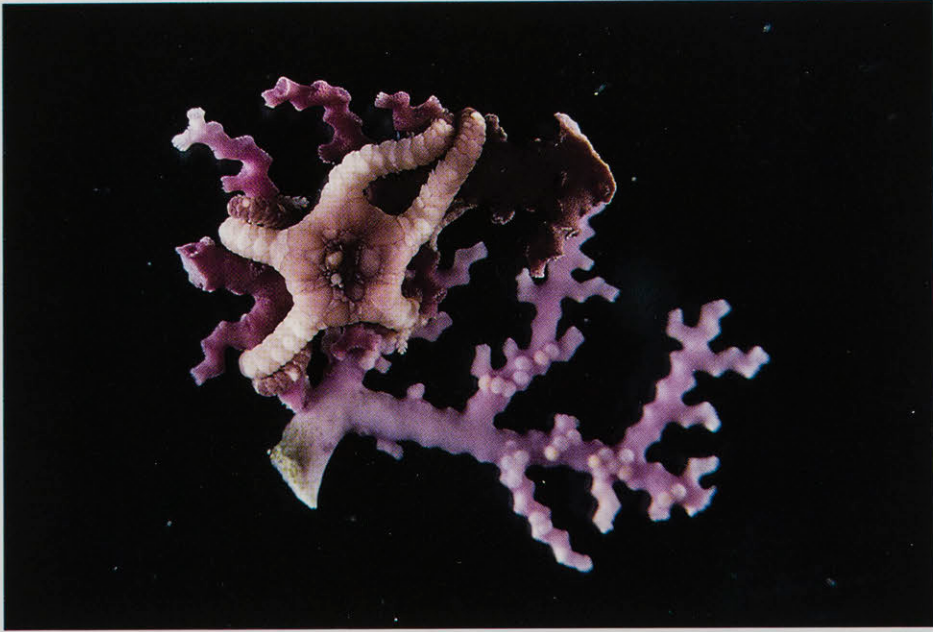
In the confusion of the spawning frenzy, brit-

tlestar oocytes and spermatozoa meet in midstream and join; the fertilized eggs are then wafted off by the water currents. The larvae that grow from those eggs play the role of "caterpillar" in the brittlestar's life cycle. They develop and grow for a few days or over a month before completing metamorphosis and the terminal transformation to a beautiful, juvenile brittlestar. Some species have large, yolky eggs and non-feeding larvae that complete metamorphosis in less than a week. Others produce hundreds of thousands of tiny eggs, which develop into more elaborate, long-lived larvae. These are translucent, microscopic creatures with a crystalline supporting skeleton, and with sinuous ciliary bands that are used for feeding and locomotion.

A minority of brittlestar species are hermaphroditic, either sequentially (transforming from one sex to another) or simultaneously. The latter may be self-fertilizing. There is a curious correlation be-

◀ OPPOSITE

This is a rare, candid picture of a brittlestar *in flagrante delicto*. The subject, *Ophiarthrum pictum*, was photographed at night on a coral reef of the Western Caroline Islands. The walls of the disc expand and contract to pump out mature gametes, which form a cloud around the disc. The gametes are suitable food for coral polyps, one possible reason that the brittlestar is elevated above the green coral colonies.



tween hermaphroditism and the means of child care: all brittlestar hermaphrodites (and only a few species with separate sexes) brood their young. That is, the embryos are held inside the parent until they have developed as miniature crawl-away babies.

Yet another small group of brittlestars, typified by *Ophiactis savignyi*, are capable of asexual reproduction by a process called fissiparity — splitting across the disc so as to produce a pair of half-brittlestars. The halves heal, regenerate missing parts, and split again when they reach a sufficient size. The young of some species with planktonic larvae, and both the adults and young of brooding and fissiparous species, often live together in special refuge substrata on coral reefs, such as calcareous algae and sponges. Small brittlestars even find shelter in the clumps of red algae that are cultivated as food, and protected from intruders by pugnacious territorial damselfishes.

The feeding behaviors of brittlestars, like their reproductive habits, are remarkably diverse. They



obtain some nutrients without lifting an arm, by the uptake of dissolved compounds through their skin. But generally, particulate food is conveyed to the mouth by the hydraulically-operated tube feet and by exertions of the muscular arms. Some brittlestars can quickly coil their arms, particularly the slender tip of the arm, and capture small active organisms, including fishes. Many species bend the arm in broad loops, like an elephant's trunk, to move larger chunks of scavenged material to the mouth. Minute particles of food may be gathered and relayed by coordinated movements of the hundreds of tube feet under the arm. The tube feet gather small particles from the surface of the sediment, snatch particles floating past in the water, or glean material adhering to the hooked or sticky, mucus-coated spines on their arms. The individual tube feet seem capable of sensing extremely dilute concentrations of chemicals such as amino acids and vitamins. Brittlestars cannot discern shapes (though they can sense light), but their chemosensory structures guide them towards food. The details of the sensory mechanisms involved, like so much of brittlestar biology, is a beguiling riddle waiting to be solved.

Our forthcoming book on the echinoderms of the Florida Keys and Bahamas will summarize the available information on almost 60 species of brittlestars, which occur at depths less than 100 feet. Perhaps the volume may contain more than everything you ever wanted to know about brittlestars. But for most brittlestar species the sum of scientific information regarding natural history can be covered generously in a few terse paragraphs, barely enough to whet the appetite of a brittlestar buff. All the same, these biological tidbits can be tantalizing: some brittlestar species spend their lives imprisoned within sponges, others can glow in the dark to repel their predators, and the miniature males of other species clasp and ride the backs of their female consorts (and the females in turn cling to the tiny spines of sand dollars). These and related brittlestar topics are worthy material for additional essays on echinoderms. However, for the true brittlestar devotee it is the discoveries not yet made and books still to be written that offer the most exciting prospects. The next brittlestar *magnum opus* on my writing agenda will be based on observations made during 100 manned



Four foraging arms of *Ophiocoma echinata* extend, upside down, from a reef crevice. Hundreds of pale, slender tube feet, two on each arm segment, fish for particles on the surface of a tide pool. They are sticky, prehensile structures, capable of sensing and capturing food particles and relaying them along the length of the arm to the mouth. That orifice, at the center of the disc, appears at the top of this picture surrounded by a crown of particularly long tube feet. A slender, brown-banded symbiotic worm, probably living off of food conveyed by the tube feet, rests on the lower surface of the second arm from the left.

◀ OPPOSITE TOP

Pink, porcelain-smooth *Sigsbeia conifera* is rarely seen, since it dwells in the dimly lit miniature recesses in coral reefs, clinging to its purplish, branching host, the hydrocoral *Stylaster roseus*. This diminutive species, less than an inch from arm tip to tip, is a brooding form that internally incubates yolk-y eggs and liberates tiny crawl-away babies. Like many brooding brittlestars, it is a hermaphrodite, and may be capable of self-fertilization

◀ OPPOSITE BOTTOM

Long-spined *Ophiothrix suensonii* is one of the most frequently photographed invertebrates on Floridan reefs. Individuals, usually in plain view, characteristically cling to sponges (as shown here) or to gorgonians. They probably use their slender, sticky spines to snare bits of food, and their tube feet to glean particles that settle onto their host. This feeding technique may clean the surface of the host — a potential benefit to filter-feeding sponges that can be fouled by silt.

submersible dives in the Bahama Islands, to depths up to 3,000 feet. Needless to say, this is some of the most exciting research that I have done, not so much because of the locale, but because of the subject — brittlestars.

Dr. Gordon Hendler is Section Head of Invertebrate Zoology and Curator of Echinoderms at the Natural History Museum. Dr. Hendler studies the systematics, functional morphology, development, behavior, and ecology of echinoderms, chiefly the brittlestars. His current museum and field research deals with the faunas of the Eastern Pacific Ocean, the Caribbean Sea, and the Gulf of Mexico.

All photos by Gordon Hendler unless otherwise noted.

The Search for Anguilla's Giant Rodent

by Donald A. McFarlane

VISITORS TO THE CHIC FRENCH tourist mecca of St. Martin will often notice a low limestone island some 10 miles to the north. Lying in the extreme northeastern Caribbean, Anguilla is only about 14 miles long and less than three miles wide. Until recently it was one of the least well known of the Lesser Antilles. In the past few years Anguilla has been "discovered" by tourism and is presently enjoying a boom in construction and development. But to the natural historian Anguilla has occupied a prominent if enigmatic position in Caribbean natural history for 120 years.

In 1868, Henry Waters & Brothers, manufacturers of phosphatic fertilizers in the city of Philadelphia, received a shipment of cave earth from Anguilla. In the 19th Century, before the discovery of huge deposits of rock phosphate in Florida, sources of phosphate were much sought after by the agricultural industry as fertilizer. Caves were frequently mined for this purpose, because the decomposition of bat guano liberates phosphorous, nitrogen and carbon compounds in abundance. Carbon and nitrogen compounds are generally lost to the atmosphere, but phosphorous combines with calcium ions from the limestone walls of the cave to form insoluble "rock phosphate." It was for the purpose of assaying the phosphate content of the cave earth that Mr. Waters had received his cargo.

Henry Waters was sufficiently astute to notice the presence of fossil bones in his shipment, and promptly brought them to the attention of Edward Drinker Cope, one of the country's preeminent paleontologists who was then employed at the Carnegie Institution in Philadelphia.

Edward Cope can hardly have been less than astounded when he was first presented with the Anguillan bones. The remains were quite unmistakably those of a rodent, but a rodent of phenomenal size. In reconstructing the animal several years later, Cope estimated it to have been approximately "the size of a Virginia deer"; later authors have supposed the animal to have been the size of a small black bear. Cope named his animal *Amblyrhiza inundata*, the generic name "*Amblyrhiza*" roughly translating to "strange root" and reflecting Cope's difficulty in conceiving of the origin of such an aberrant beast. The specific name "*inundata*" alludes to Cope's conten-

tion that the presence of so large an animal on so small and remote an island evidenced the existence of a founded (or inundated) land-bridge between the Antilles and South America.

The bones that Cope received from Waters' serendipitous Philadelphia shipment were far from complete, but Cope was well aware of the importance of Waters' find. Accordingly, on learning that the resident physician on Anguilla's neighboring island of Dutch Sint Maarten (the northern two thirds of this same island being French St. Martin) was a keen amateur natural historian, Cope asked Dr. Rijgersma to travel to Anguilla and to attempt to secure additional remains of the rodent. Anguilla lies within sight of St. Maarten/St. Martin, and Rijgersma was able to make several trips, ultimately recovering a wealth of additional material. The majority comprised broken leg bones, vertebrae, and teeth from numerous individuals of different sizes. The precise source (or sources) of the bones was not recorded in any known contemporary document, and the only contextual information that Rijgersma provided was the fact that they came from one or more caves being mined for phosphate. On the basis of the apparent size of the former mining operation, David Carty of the Anguilla Archaeological and Historical Society believes that the original bones came from a site now called Cavannagh Cave, although there are other possibilities.

Cope summarized his findings in a Smithsonian Institution report of 1883, and there the matter rested until it was taken up by H.E. Anthony of the American Museum of Natural History in 1926. Anthony also believed that the Antillean islands must have had a former land-bridge connection to North or South America, and in the search for evidence of a former, more diverse fauna he undertook a series of expeditions to the Caribbean in the 1920s. In Jamaica, Anthony discovered and described an extinct relative of *Amblyrhiza*, a rabbit-sized rodent which he called *Clidomys*. On Puerto Rico he unearthed another member of this enigmatic, extinct family, the similarly-sized *Elasmodontomys*. Anthony searched for *Amblyrhiza* on Dutch Sint Maarten, where Rijgersma had some success, but recovered only a few tooth fragments. Pressed for time, but not wishing to give up on the search, Anthony sent his field assistant, George Goodwin, to Anguilla and embarked for St. Thomas (then part of the Dutch Virgin Islands). Goodwin arrived on Anguilla on Wednesday, March 31, 1926 after an hour and a quarter crossing on the sloop *Speed*. After several days' search, Goodwin located some *Amblyrhiza* skull fragments in a cave at Flat Cap Point, and subsequently a variety of tooth and bone fragments from small caves on the North Side Estate and at a site he called Brimingham Hollow.



Crocus Bay, which lies between Flat Cap Point and Katouche Bay in the heart of "*Amblyrhiza* Country."

OPPOSITE ►
Southern capybara.





Assistant Florian Reber descends into Pitch Apple Hole, beside the roots of a Pitch Apple tree.

ABOVE RIGHT

Partially concealed in the forest, Pitch Apple Hole is a potentially lethal, 60-foot deep natural trap.

The large extinct rodents of the Antilles together make up the family Heptaxodontidae, and are found nowhere except the Greater Antilles and the northern Lesser Antilles. The heptaxodontids are caviomorph rodents, that is, they are distantly related to the guinea pig, the rabbit-sized agouti, and the four-foot capybara, the largest living rodent (see sidebar, page 39). Whilst the heptaxodontids are quite distinct from any living rodent, their affinities are with the rodents of South America, some 650 miles to the south, rather than with those of North America only 90 miles or so to the north. Their presence in the Antilles is therefore surprising, and their biogeographic history is as great a puzzle to mammalogists today as it was to Cope and Anthony two generations earlier.

For many years, it was in vogue to consider that the heptaxodontid rodents survived in their Caribbean redoubts until the 16th Century, when the combined onslaught of forest clearance, hunting, and the introduction of dogs, cats, mongooses and true rats that accompanied both the Indian and Afro-European colonization finally drove them to extinction. During the past decade, it has become widely believed that the wave of extinctions that decimated the large mammals of continental North America at the end of the last Ice age may be attributed to the simultaneous arrival of the first human hunters. These Clovis people (so called because of their association with distinctive lance points dating from 9,000 B.C. that were found at Clovis, New Mexico) entered North America by migrating across the Bering Straits from Asia, and are regarded as sophisticated hunters who were unquestionably successful in killing mammoth and other large game. By analogy to this theory of "overkill" of ice-age mammals by the first Americans, it has been frequently suggested that the heptaxodontids were a naive (unaccustomed to predators) fauna, exterminated by the newly arrived Arawak and Carib Indians of the Caribbean sometime after 3,000 B.C. Unfortunately, hard evidence for this idea is lacking in the case of the heptaxodontid rodents, the giant ground sloths of Cuba and Hispaniola, and other enigmatic Antillean mammals.

In 1985, Ross MacPhee, Derek Ford, and I began a careful study into the age of the *Clidomys* remains from Wallingford Cave, Jamaica, originally found by H.E. Anthony in 1920. We would eventually be able to show that these fossils were between 140,000 and 160,000 years old. No younger dates for *Clidomys* have yet been obtained. Like Cope and Anthony before us, MacPhee and I were intrigued by the presence of *Amblyrhiza* on Anguilla and Sint Maarten, and we were dissatisfied with the widespread opinion that the beast had fallen prey to the original native West Indians. In fact, the evidence for the contemporaneity of *Amblyrhiza* and man is extraordinarily weak. In his original 1883 summary of



his *Amblyrhiza* studies, Cope described an Indian tool — a shell scraper — in his shipment of material. Cope was careful to point out that there was no stratigraphical information to suggest that the tool and the fossil were contemporaneous. Nevertheless, several generations of archaeologists and paleontologists have chosen to suppose just such a connection, and to infer that *Amblyrhiza* must have ended its days on an Indian griddle. The fact is that no evidence, contemporary or otherwise, exists to support the contention that the artifact was recovered from the same deposit and level as *Amblyrhiza*, or even from the same cave. All the specimens came from phosphate mining operations, not careful paleontological excavations. Neither Cope nor Rijgersma recorded the name or names of the caves from which materials were recovered, and Cope even confuses specimens from Dutch Sint Maarten with those from Anguilla. No archaeological midden on either St. Maarten/St. Martin or Anguilla has yet yielded a single *Amblyrhiza* bone, despite the presence of human bones, midden deposits and artifacts dating back several thousand years.

If the evidence that *Amblyrhiza* survived until the arrival of man is entirely lacking, the alternative — that the animal died out perhaps millennia before the arrival of human colonists — is equally unsupported by hard evidence. The original fossils, collected without any details of their stratigraphic dispositions, were of little help in resolving the issue. MacPhee and I needed datable fossils from a documented stratigraphical context to shed light on the problem, and the only option open to us was to go to Anguilla and the neighboring islands to search for new specimens. This line of reasoning was hardly original and had inspired a succession of visitors over the years, but no one had made any significant discoveries since Goodwin departed with his finds almost 60 years earlier.

When Ross and I arrived on Anguilla in May of 1988, we were well aware that our chances of success were slim. Vertebrate fossils in the Antilles are almost exclusively found in caves, where they are protected from the harsh tropical environment. On a



small island like Anguilla, caves are a limited and finite resource, and only a tiny fraction of them could be expected to contain fossils. Nevertheless, some months previously Ross had located Goodwin's original field notes in the American Museum of Natural History, so we had a foundation to build on. We planned to return to Goodwin's sites, reconstruct the stratigraphy of the finds, and perhaps recover additional specimens.

Unfortunately, Goodwin's notes proved less helpful than we had hoped. Lacking standardized topographic maps, he had confused several localities and referred to others by local names — such as Brimingham Hollow — which have not survived. As a result, we were not able to relocate any of Goodwin's fossil sites with useful precision.

It was soon apparent that before we could locate the rodent fossils, we would have to locate caves suitable for trapping such beasts and preserving their bones. Anguilla has no shortage of limestone — the principal bedrock in which caves are found — but it does lack both the surface streams and the significant topographic relief that promote cave formation. Small pits and hollows abound on the island, but significant caves are rare and have never been systematically documented. However, the most productive approach to finding caves in tropical bush is often to seek the advice of local farmers, and this proved almost immediately successful.

In the dry tropical forest of Anguilla, certain moisture-loving trees tend to grow where they can extend their roots into the damp interiors of deep caves. The most distinctive of these trees are known locally as pitch-apple trees, and to the experienced eye they can be recognized at a distance by their

large, dark green leaves. Thus it was that Ross and I were directed to a large pitch-apple tree in the forest of the North Side Estate. Pitch-Apple Hole, as we came to call the site, proved to be an impressive gaping mouth in the forest floor. Tree roots extended down from the surface to the boulder floor some sixty feet below. Rappelling into the chasm, we quickly established that the cave was not very extensive but it did preserve a small area of red cave earth at its lowest point. A few moments of digging yielded our quarry — first an incisor tooth and then a large leg bone that clearly did not belong to any animal now living on the island. We had found *Amblyrhiza*.

In the week that followed, our excavations unearthed a remarkable collection of *Amblyrhiza* bones belonging to at least four individuals. The animals had obviously fallen into the cave and their bones had accumulated at the lowest point in the pit. The bones were fractured, but many parts of the skeleton were represented. We also collected sizable quantities of the bones of a large iguana, several birds, and two species of bat.

As often happens, finding the fossils was to prove easier than dating them. The simplest approach to dating bones is probably the radiocarbon technique. The procedure is based on the fact that the atmosphere around us contains minute quantities of a radioactive isotope of carbon. This isotope — carbon¹⁴ — is incorporated into the food chain by the normal photosynthetic activities of plants and ends up in the tissues of animals. After death, the carbon¹⁴ in the organic component of bone is no longer replenished and begins to disintegrate by radioactive decay at the rate of one half of the starting amount for every 5,568 years. Thus, a bone can be dated by extracting its organic component and measuring the quantity of carbon¹⁴ remaining. Unfortunately, a large sample of *Amblyrhiza* bone fragments submitted for radiocarbon dating proved to have almost no remaining organic carbon, and certainly too little for analysis. Such a circumstance might be the result of great age, but it could equally have resulted from accelerated decomposition in a warm, moist cave environment.



The cliffs of Little Bay conceal the entrance to Little Bay Phosphate Cave, a probable *Amblyrhiza* site of the 1926 expedition.



Steven Melendrez (after L. Meeker, American Museum of Natural History)

A reconstructed *Amblyrhiza inundata*, broadly capybara-like but with very robust hindquarters.

With radiocarbon dating no longer a viable option, the successful dating of *Amblyrhiza* once again depended on additional collecting on Anguilla and its satellite islands. Some of the early *Amblyrhiza* finds were embedded in a matrix of calcite, the mineral that forms stalactites and stalagmites in caves. It is now possible to date such calcite by the radioactive decay of trace amounts of uranium contained within it, and we had used this technique successfully with the Jamaican *Clidomys* fossils. The 19th-century *Amblyrhiza* fossils are not associated with a large enough quantity of calcite to date, but the 1988 fossils were buried in a cave sediment deposit beneath a calcite shelf. Derek Ford of McMaster University, Toronto, has analyzed samples of this calcite for traces of uranium and the daughter isotopes to which it decays using a newly developed mass spectroscopy technique. The results reveal that the calcite was deposited over the fossil-bearing sediments between 102,000 and 106,000 years ago (give or take 5,000 years).

In the summer of 1989 Ross and I resumed our search for *Amblyrhiza*. After a week and a half of unsuccessful searching across the length and breadth of Anguilla and its offshore islands, we were taken to a small, insignificant hole in an area of Anguilla known as Tanglewood. Tanglewood cave was only nine feet deep, but its low, wide chamber was floored with the characteristic red cave earth of our earlier finds at Pitch-Apple Hole. A few minutes' search brought to light an enormous incisor tooth, more than six centimeters long. We had our second *Amblyrhiza* locality. In the two days remaining to us, Ross and I worked with members of the local Archaeological Society to recover the bones of what appears to be a single animal. The bones so far recovered include portions of the skeleton not found in 1988, but lack the intimate calcite association we had hoped for. I therefore suggested to Derek Ford that he attempt to date the Tanglewood teeth by an alternative method, called Electron Spin Resonance (ESR) dating. The principle involves

measuring the quantity of free electrons that accumulate in the natural defects of a crystalline matrix (such as tooth enamel) under the continual bombardment of natural background radiation. We anticipate that this technique will shortly reveal the age of the Tanglewood fossils.

In August 1990, I returned to Anguilla to continue work at Tanglewood Cave. Our brief excavation the previous year had turned up several pieces of charcoal and a few flint-like chert artifacts, and it was necessary to determine whether a stratigraphical (and hence chronological) association existed between the owners of the artifacts and *Amblyrhiza*. Ross was unable to join the work following a car accident in Cuba, where he was working on a related project involving the fossil monkeys of that island. Fortunately the Anguilla Archaeological and Historical Society, under the capable direction of Nik Douglas, rallied to the cause and together we were able to make a further collection of *Amblyrhiza* fragments and establish to our mutual satisfaction that these were not stratigraphically associated with the Indian artifacts.

The 1990 field work also revealed two further interesting sites. By squeezing through a narrow opening in the forest floor of Katouche Valley, I was able to enter a small room which I have called Mitchell's Chamber after local historian Don Mitchell, who brought my attention to the site. On one wall was a substantial calcite shelf containing isolated teeth of *Amblyrhiza*. Uranium series analysis of this calcite is expected to reveal the antiquity of these teeth in the near future.

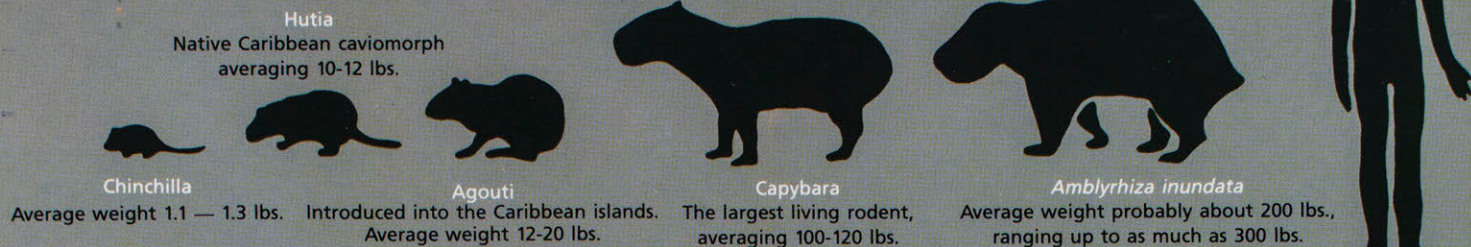
In the final days of the 1990 fieldwork, I took a closer look at the cliffs of Flat Cap Point that had proved productive for Goodwin in 1926. By swimming along the base of the cliffs I was able to spot a cave opening into the cliff face some 80 feet above me and perhaps 40 feet below the cliff edge. After cutting a path through the tangled thorn scrub with a machete, I was able to rappel down into the cave and discover the telltale shot-holes of a former phosphate-mining operation. The cave, which I have called Little Bay Phosphate Cave, closely matches one of Goodwin's descriptions and I am confident that I have re-discovered one of his sites. Unfortunately, a thorough examination of the cave in August 1991 revealed that the mining operation had completely destroyed the original deposits.

After 120 years of obscurity, *Amblyrhiza* has begun to yield its secrets. Cope did not attempt a reconstruction of the animal based on his fragmentary material, and the wide range of limb bone sizes led him to propose the presence of three separate species of *Amblyrhiza* on the islands of the Anguilla Bank. Most authors have subsequently presumed only a single species (three different giant rodents on

Amblyrhiza bones from Pitch Apple Hole. The scale is indicated by the camera lens cap.



The Cavy-Like Rodents



THE CAVIOMORPH RODENTS are a disparate group of thirteen families of living New World rodents and an uncertain number of extinct families. The caviomorphs include the world's largest living rodent, the 90-150-pound capybara, the common guinea pig, and the prized chinchilla, all loosely united by common fea-

tures of their dentition and jaw structure. Caviomorphs are a South American group, although a few species have spread north into Central America and one living family, the hutias, successfully colonized the West Indies in the distant past.

The living West Indian hutias are robust, short-tailed animals weighing 7

to 15 pounds. Several extinct forms are known from the Greater Antilles, and at least one is known primarily from bones recovered from Indian middens. *Clidomys* and *Amblyrhiza* are grouped by most authors in an extinct family, known only from the Greater Antilles, Anguilla and Sint Maarten, called the Heptaxodontidae. However, because the fossil re-

mains of these animals are so fragmentary, the relationship of the heptaxodontids to other caviomorphs remains uncertain and controversial.

Certainly, the heptaxodontids are sufficiently distinct to have no close living relatives, and we can safely assume that they have been in their Caribbean redoubts for a very long period of time.

such small islands seemed quite improbable) and our work has confirmed this. By measuring the cross-sectional area of the animals' leg bones and comparing these with the leg bones of living rodents of known body weight, we have been able to develop a statistical model that has led us to conclude that the beasts were even larger than Cope had supposed — some individuals may have weighed almost 300 lbs. We believe that much of the variation in limb bone size, which led Cope to split the genus into three species, can be accounted for by sexual dimorphism; male caviomorph rodents are often significantly larger than the females. *Amblyrhiza* is also structurally unlike any other known rodent, with enormously robust and powerful hind legs but gracile, almost delicate forelegs. This difference in proportion of the fore and hind legs probably also contributed to misleading Cope.

Despite its disproportionately robust hind limbs, *Amblyrhiza* was unlikely to have been a biped. Its feet are short and quite unlike those of kangaroos and other bipedal, hopping mammals. We believe that *Amblyrhiza* was a scratch-digger, occupying a quite different niche than the world's largest living rodent, the 150-lb. semi-aquatic capybara, to which *Amblyrhiza* appears superficially similar.

Other aspects of our work remain unresolved. We cannot yet suggest when the last of these giant rodents walked the islands of the northeastern Caribbean. It is a perennial problem of Quaternary paleon-

tology that a dated fossil can only tell us when an animal was alive, never when the last of the line died out. Setting a date on a prehistoric extinction is a matter of marshalling circumstantial evidence. At the present time we can say that all dated specimens of *Amblyrhiza* predate the arrival of man by many tens of thousands of years. We have also established that there is no unequivocal association between *Amblyrhiza* at any known archaeological site on Anguilla or St. Maarten/St. Martin, a fact that would be remarkable if indeed Indians and giant rodents had ever shared these islands.

Studies of *Amblyrhiza* and its relatives on the other Antillean islands have been a fruitful source of theory on the prehistoric ecology of these islands, and of the nature of the extinctions that changed the character of the islands forever. We fully expect that continuing investigations in the caves of Anguilla, and in the laboratories of the American and Los Angeles County Museums of Natural History, will turn up new insights into the processes that shaped the modern ecology of these fascinating islands.

The drawing of *Amblyrhiza inundata* on page 38 first appeared in *Anguilla Life*, vol. 2, no. 3, 1989.

Donald A. McFarlane received his doctorate from the University of Southern California in 1987 while a Student-in-Residence at the Natural History Museum of Los Angeles County, working on the ecology of Caribbean bats. He is presently an Assistant Professor of Biology at the Claremont Colleges and a Research Associate in the Section of Mammalogy at the Natural History Museum. His current interests include the biogeography of island mammals and the ecology of bats in the insular tropics and Southwest U.S.A.



Zoological Society of San Diego

All photos by Donald A. McFarlane unless otherwise noted.

◀ LEFT
Grey's agouti, a common, mid-sized caviomorph.

Focus on the West

The Photographs of Warren C. Dickerson

IN 1905 A GROUP OF LOS ANGELES businessmen raised funds to purchase the Downey Block at the corner of Temple and Main streets. Ashamed of the "mean quarters" that housed the post office, these public-spirited citizens presented the property to the U.S. Government as the site for a new federal building. Congress appropriated \$800,000 for the construction of the facility, but according to Harris Newmark (one of the above-mentioned public-spirited citizens), "it was with no little surprise and disappointment when the bids for construction were opened in May, 1906, that the lowest was found to be nearly a million dollars." Fortunately, the proceeds of the sale of the original post office building at the corner of Main and Winston streets provided sufficient cash for construction to begin.

This picture was taken by Warren C. Dickerson in late 1906 or early 1907 as work progressed on clearing the land for construction. The new Post Office and Federal Building stood on this site until the 1930s, when, as part of the master plan for the Civic Center, it in turn was demolished to make way for the Federal Court Building which now stands at this location.

In the background, at the corner of Main and Commercial streets, is the Ducommun Hardware store. Established in 1849 by a Swiss immigrant named Charles Louis Ducommun, the company has grown into a large manufacturing corporation and has the distinction of being the oldest continuously-operating business in Southern California.

This photograph is from one of about 14,000 glass negatives in the Warren C. Dickerson collection, which includes turn-of-the-century photographs from 28 states as well as Canada and Mexico. Approximately a third of the collection consists of images of California and Los Angeles. Like the picture presented here, many of Dickerson's photographs show ordinary people as they went about their lives and work.

Unfortunately, we know very little about Warren C. Dickerson other than the fact that he was somehow involved in the postcard industry (many of his images appear in the Seaver Center postcard collection) and that he died in Los Angeles in 1936. The photographs that he left behind provide invaluable social portraits of America at the turn of the century.

ERROL STEVENS
Curator, Section Head
Seaver Center

Focus on the West is a TERRA feature that presents the photographic highlights of the museum's Seaver Center for Western History Research. The Seaver Center is rich in photographs and other materials relating to the history of the American West.



Warren C. Dickerson Collection, P-5, Box 89

The Natural History Museum Hits the Road

IN FEBRUARY 1991, THE NATURAL HISTORY Museum of Los Angeles County received a generous grant from the Maxwell H. Gluck Foundation to build the Earthmobile, a mobile museum that brings science to elementary school children of the Los Angeles Unified School District. Designed for third through sixth grade students, the Earthmobile's activities encourage children to examine the place, role, and impact of humans in the natural world.

In conjunction with the school district, the museum's Education Division has developed curricula for teachers to use before and after Earthmobile visits, as well as a separate training program for teachers. Lessons are augmented by performances by the highly acclaimed children's theater company *We Tell Stories*. This troupe is with The Performing Tree, Inc., a non-profit arts and education organization.

Using archaeology, we examine the past, present, and future of southern California. A truly integrative discipline, archaeology exposes students to an extraordinary array of other sciences — most of

them thoroughly represented here at the Natural History Museum. Through analysis of the objects they uncover in a simulated "dig," students learn about ornithology, marine biology, mammalogy, paleontology, mineralogy, and botany, as well as anthropology, history, and ecology. Through archaeology, children explore interrelationships within the natural world, and are led to the discovery that the people who lived here long ago knew the arts of belonging to that world. These insights give children a sense of the continuity of life, of the responsibility of humans to pass the earth on to future generations, and of their own role in living in the world they have inherited.

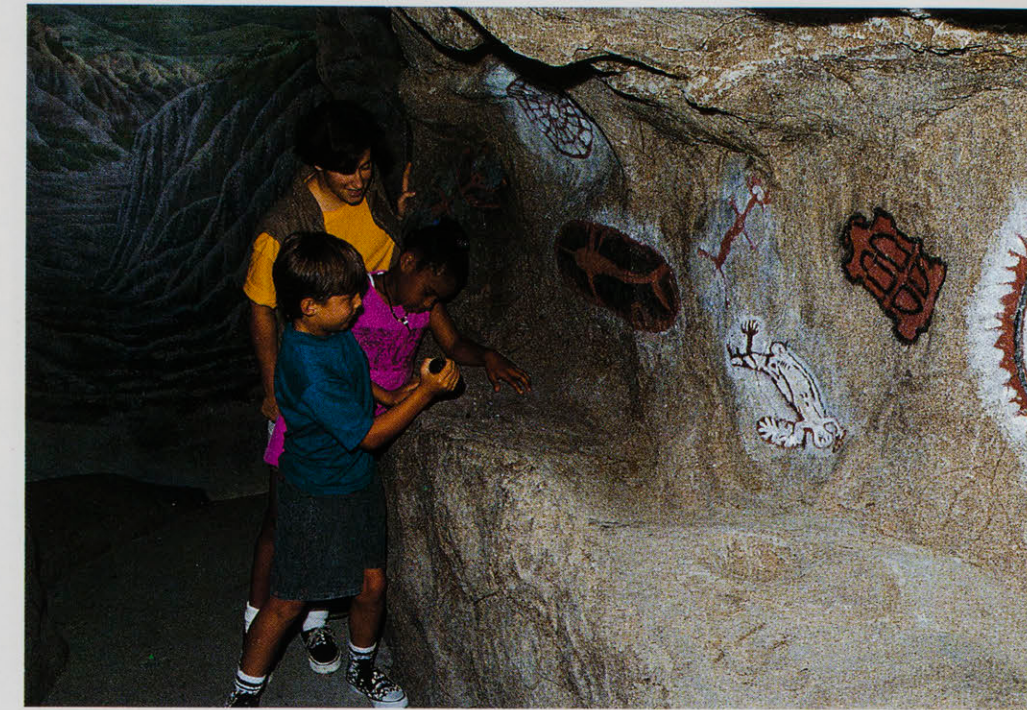
Dressed in vests laden with the scientific tools of archaeologists, they step into the 48-foot-long by eight-foot-wide trailer, inside which is created a fictional coastal canyon, Arroyo de las Ventanas, in the Santa Monica Mountains. The canyon entrance is framed by the branches of a coast live oak. Entering the canyon, students see the remnants of a Native American encampment and a shallow cave covered with pictographs (rock art). Two bedrock mortars

used by the local Native Americans to grind acorns and other food items can be seen on a rocky ledge. A sandy wash imprinted with animal tracks runs along the floor of the arroyo.

Farther down the canyon are traces of a recent brush fire. Burnt and fallen vegetation, including the remains of an oak, lie in the burn area. But poppies, phacelias, monkey flowers, and lupines are in full bloom, beginning the restoration process. Throughout the canyon can be seen and heard specimens of the birds, mammals, reptiles, and insects of the chaparral, including bobcats, coyotes, Scrub Jays, Acorn Woodpeckers, California Quail, California king snakes, and ceanothus moths. Fossils, including shark teeth, clams, and oysters, jut out from the sandstone. Recent rains, the young archaeologists are told, have carved jagged incisions in the strata and carried fossil material into the wash.

In a mural at the end of the truck, the present-day city of Los Angeles is visible far off in the distance across a pristine grassland.

Five small archaeological excavations line the canyon's north wall. Across from these, rough-hewn



John De Leon

Beneath Chumash pictographs, students grind acorns into meal.



Mike Meaker



Don Meyer

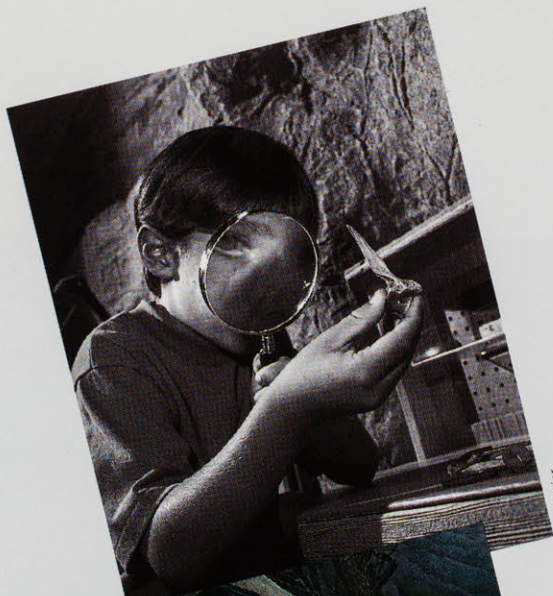
camp tables containing scientific equipment sit against the foot of the canyon's south slope. Five teams, made up of three students each, uncover artifacts and natural objects in the simulated dig sites. Items include an acorn, quartz crystal, a chert arrowhead, an obsidian spearpoint, a feather, abalone shell, olive shell, some walnut-shell dice, a pocket gopher jawbone, a fossil snail shell, limb bones from a gull and a raccoon, a shell fishhook and even a soda can. Across the canyon at the field laboratory, the students identify their artifacts, weigh and measure each one, and record their findings in field notebooks. Through a set of self-guided activities, they learn about each object's role in the ecosystem and how each was used by the local Native Americans. Perhaps most importantly, students learn throughout their Earthmobile experience that archaeology is a science, and that digging on their own is illegal and damaging to our understanding of past cultures.

Other Earthmobile activities include grinding seeds at the bedrock mortars, casting animal tracks, recording pictographs, making rubbings of fossils, touching taxidermied specimens, and making maps.

At the end of the students' archaeological expedition, they receive a surprise visitor. An archaeologist from 300 years in the future "beams" in to talk to them. She discusses the findings of *her* excavation, including the discovery of many items she concludes are fuel containers from our vehicles (they are actually soft drink cans). Through the magic of special effects, students see what the canyon might look like in the future if the changes that are occurring to animal populations around the Los Angeles basin continue. The archaeologist's take-home message to the students is that by caring for the past and protecting the present, they can make a difference in the future.

JUDITH L. CHOVAN
Section Head, Science Education

Students closely examine artifacts such as this tuna vertebra. Below, a pocket gopher peers from under a burnt log.



Dick Meier



John De Leon

Book Reviews

WATER BABY, THE STORY OF
ALVIN

by Victoria A. Kaharl

Oxford University Press, \$21.95

ALVIN IS A CUTE, STUBBY little pale yellow submarine. This account of Alvin's origins and the first 25 years of its service was supported by grants from the U.S. government, which owns and supports Alvin through contracts with the Woods Hole Oceanographic Institution on Cape Cod.

The habitable part of the submarine is a titanium (originally steel) sphere about 2 m (7 feet) in diameter. At least a quarter of the interior is taken up with electronic gear, leaving scant space for a pilot and two observers. The viewing ports in the hull are directed in such a way as to guarantee maximum discomfort for anyone but a midget, and an 8-to 10-hour dive eventually seems like a pretzel convention. The sphere is mounted on a fiberglass-covered aluminum frame that encases ballast tanks and the batteries that power *Alvin*, and also supports the propellers that drive it. In addition there is a movable arm supporting a manipulator, and a changeable array of lights, cameras, sensors, samplers, and containers. The whole is capped by a conning tower that looks like a great place to ride but is flooded during dives.

The special thing about *Alvin* is that it can dive as much as 4000 m (2.5 miles) into the deep sea and scientists can look out of the ports and direct the collection of animal, geological, and chemical samples, arrange experiments, and make fine-scale measurements and observations. Although other research submersibles can dive deeper, none are as versatile; still others have better visibility and can do more kinds of work, but only at shallower depths.

Water Baby concentrates on the human side of *Alvin*'s origins, design, construction, testing, and uses. It tells a little bit about a lot of people and perhaps too much about a few. The human side being what it is, some people one

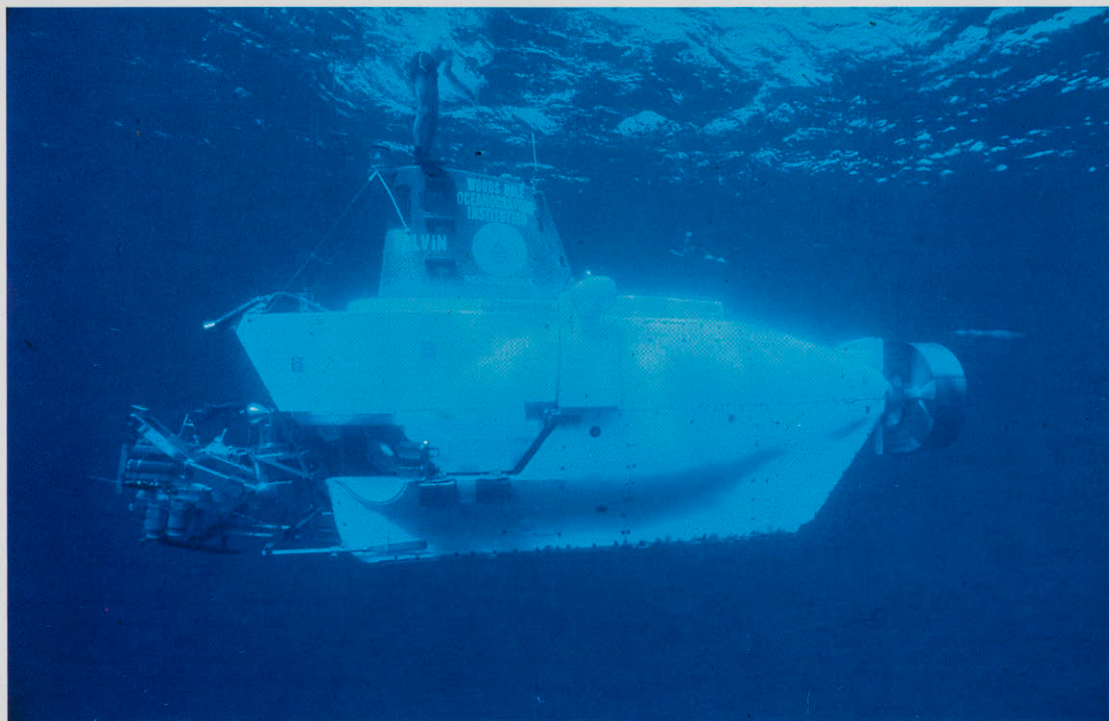
would have thought important are scarcely mentioned or omitted entirely.

I think the book is wonderful because of my own long preoccupation with deepsea fishes. For years I had studied dead ones caught in nets and traps, and even though I had viewed thousands of remote pictures, I yearned to have a firsthand look at living ones and where they live, far below SCUBA depth. Even after research submersibles became available, there seemed to be an endless

much about the maneuverings of science policy and the apparently whimsical decisions that contributed to the genesis of the submersible and more than once threatened the continuing existence of the project. The details of design, construction, and certifications were mostly new to me. Would I have entrusted my life to *Alvin* if I had known what this book tells?

But more than anything the book is a series of anecdotal accounts of the crew who ran and

special accounts are given of *Alvin*'s role in the discovery and recovery of a lost atom bomb from deep water in the western Mediterranean, of the loss and recovery of *Alvin* from a depth of more than 1500 m (5000 ft.), of cooperative U.S.-French explorations of the spreading zone along the Mid-Atlantic Ridge, and perhaps most famous of all, of *Alvin*'s series of dives to investigate the astonishing and completely unimagined biology, chemistry, and geology of deepsea hot



Woods Hole Oceanographic Institution

stream of engineers, inspectors, administrators, directors, Navy officers, politicians, journalists, and architects of secret projects to be accommodated. But finally my chance came, and since 1972 I have had the privilege of participating in *Alvin* dives off New England, in the Bahamas, and to underwater hot springs in the tropical eastern Pacific. My original sense of excitement and discovery is still with me.

Although I already know something about the more important scientific discoveries made by *Alvin*, I learned from *Water Baby*

maintained *Alvin*, of the scientists who used it, and of their discoveries. Although morale and pride have always been high in the *Alvin* group, *Water Baby* tells of the persistent conflict between the practical crew and technicians who live uncomfortable and often dangerous lives at sea, and the single-minded scientists, temporary visitors who sometimes appear arrogant and overbearing. Another topic of the book, in no way overstated, is the battle of women to take their place as equals at sea.

Among the many wonders of the deep that are described,

springs. The discovery of the wreck of the *Titanic*, a questionable enterprise for *Alvin*, could have done with less coverage.

Even though the book verges on being more of a public relations exercise than an even account and evaluation of an important chapter in American oceanography, it is fun to read and was obviously written with careful attention to fact.

DANIEL M. COHEN
Division of Life Sciences

Exposition

Q: We've heard so much about the freeway foxes in the news; why is the State of California so reluctant to move them to another site?

A: The "freeway foxes" that were living on the new freeway in Orange County are red foxes, members of the species *Vulpes vulpes*, which is not native to southern California, according to Sarah George, Associate Curator in the Section of Mammalogy. In fact, there were no established populations of red foxes

along the southern California coast from Point Mugu to San Diego County. The largest populations appear to be in coastal salt marshes and the oldest known population is at the El Dorado Nature Center in Long Beach.

This non-native species has had marked effects on other species that always have lived in southern California. An endangered species at the Seal Beach National Wildlife Refuge, the Light-Footed Clapper Rail, was preyed upon by red foxes and its

breeding disrupted to the point that virtually no baby birds survived. Red foxes were threatening a breeding colony of another endangered species at the refuge, the Least Tern. The U.S. Fish and Wildlife Service intervened and removed red foxes from the refuge. Red foxes out-compete gray foxes in the selection of dens and there is some concern that they will replace our native gray fox, *Urocyon cinereoargenteus*, in areas of southern California. Red foxes recently established in central Cali-

fornia are known to kill and replace the endangered San Joaquin kit fox, *Vulpes macrotis mutica*.

Elimination of several native bird and mammal species by the thoughtless introduction of red foxes is a real fear in southern California. In the Aleutian Islands of Alaska, introduced red foxes have dramatically reduced populations of seabirds, virtually eliminating them in some cases; foxes have driven the Aleutian Island Goose, for example, to the edge of extinction. Southern California's coastal salt marshes act as islands for native wildlife in an urban sea, and a similar catastrophe could be in the making here.

The consequences of moving red foxes such as the freeway animals to another area and letting

them go are severe. Whenever an animal is transplanted, chances are very good that it will either die or replace an animal already living there, by competing for food and den sites, or by killing it outright. Transplantation rarely results in happy coexistence for both the native and introduced species. If red foxes are moved to areas where there are already native populations of red foxes, such as out of state, the introduced animals might bring with them disease or parasites that the native populations cannot withstand. Red foxes are, for example, one of the primary vectors of rabies, and because they adapt so well to urban life, they are more likely to transmit it to pets and people than the native gray fox. That is one reason why the State of California (along with all the other states consulted) is not interested in moving red foxes to other areas.

There are no simple solutions to the problem. Transplantation brings risk to both the transplanted and native animals. Existing populations of red fox in southern California are too large and widespread to eliminate (as efforts in other parts of the world have demonstrated). Our only hope now is to control populations and minimize their effects on the native species they threaten — the rail, the tern, and our native foxes. We must think of present and future generations of Californians whose environmental heritage is at risk.



L. Master, The Nature Conservancy



Red fox, *Vulpes vulpes*

ABOVE RIGHT:

Gray fox, *Urocyon cinereoargenteus*

The museum's staff members are often asked to answer historical questions, or to identify artifacts and specimens that people have found, purchased, or inherited. Exposition is a feature of TERRA in which the museum's staff will discuss interesting questions frequently asked them by museum members and the general public.

in southern California until the late 1960s or early 1970s. The oldest specimen that George has been able to locate in museum collections is an animal that was killed by a car in 1967 in the San Fernando Valley; it had a pet collar on it and had probably escaped.

It is not clear how red foxes were introduced to southern California. Red foxes were released for hunting in the early 1900s, but it doesn't appear that those animals established breeding populations. There were fox-fur farms in the area, and people have kept foxes for pets. It is probably a combination of inadvertent escapes and deliberate releases of foxes that led to the establishment of the populations seen today

Southland Diorama

A SEASHORE EXCURSION AMONG THE rocks at low tide offers unique opportunities to view the myriad of invertebrates in a habitat most of us would consider quite inhospitable. Indeed, species attached directly to rocks in the intertidal zone must not only contend with pounding surf, but also exposure to high temperatures, desiccation, and predators during low tide. One of the most common adaptations of intertidal invertebrates to this environment is the secretion of a hard, shell-like covering or skeleton, such as the shell of mollusks, the exoskeleton of barnacles, or the calcareous plates of sea urchins.

Many soft-bodied invertebrates, however, lack such intrinsic protection and have had to solve this problem by other means. A species along the central and southern California coast that has met this challenge with obvious success is the segmented worm, *Phragmatopoma californica*.

Marine segmented worms, known as the Polychaeta (pronounced poly-keeta), are distant relatives of earthworms and leeches. The most distinctive feature of polychaetes is the presence of paired bundles of hair-like bristles on all or most body segments (from the Greek *poly* = many; and *chaeta* = bristles). Most beachcombers are unaware of the vast numbers of worms inhabiting ocean bottoms at all depths and the vital role polychaetes play within marine ecosystems. The cryptic habits of *P. californica* certainly make it no exception to this rule. With one of the world's largest polychaete collections, however, the Los Angeles County Museum of Natural History affords excellent opportunities to study the relationships and interactions of polychaetes.

The colonies of *P. californica*, commonly known as the "honeycomb worm," are easily recognized by their tube masses, which house several hundred to thousands of individuals. Colonies can form small reefs up to 2 meters across, whereas an individual worm is no more than 5 centimeters in length. By contrast, colonies of some species from Florida, Great Britain, and South America are so large that they form massive reefs upon which sunbathers lounge. Each worm occupies its own tube, which it constructs of sand grains collected from the swirling water during high tide. Experiments have shown that *Phragmatopoma* actively selects sand grains of a certain size, discarding those too large or small, and then cements each grain to the tube wall with mucus secreted by the worm. The tubes in a colony lie parallel to one another in a very dense, orderly pattern. With each tube opening at the surface of the mass, the colony has a distinctive honeycomb appearance. When removed from its tube, *Phragmatopoma* cannot build a new tube, but it can repair damage to an existing tube.

The name *Phragmatopoma* refers to the modifi-

A genus and species of sabellariid polychaete from Australia which is closely related to *Phragmatopoma*. The small white objects around this specimen are eggs, which the worm spawned upon being removed from its tube to be photographed.



©Kathie Atkinson



Closeup of part of a colony of *Phragmatopoma californica* from the intertidal zone along southern California. Note the honeycomb appearance of the tube openings.

cation of several pairs of bristles near the head into a thick, cone-shaped plug or operculum (from the Greek *phragmato* = hedge; and *poma* = cover) which, when the worm retracts back into its tube, can block the tube entrance from predators, as well as preventing the worm from drying out during low tide. The head region also has numerous short tentacles which the worm extends out of the tube during high tide to feed on plankton or collect sand grains.

Phragmatopoma has a rather complex life cycle. Adult worms release eggs or sperm into the water, where fertilization takes place. Microscopic larvae soon develop, and swim in the water for three to five weeks. Prior to metamorphosing into a juvenile form of the adult, a larva will swim just above the rocks, periodically "tasting" rock surfaces. Experiments with a number of *Phragmatopoma* and related species have shown that this "tasting" behavior is the means by which larvae determine the suitability of potential settling sites. The key element required for inducing settlement and metamorphosis of larvae is the presence of cement secreted by adults of the same species, which the larvae detect during their periodic "tastings" of surfaces. This larval behavior has several advantages: it increases the chances of larvae settling on an established colony, it increases a juvenile's chances of survival, and it affords colonies the opportunity to continue growing, which increases the chances of each colony's survival.

What importance could we ever attribute to the study of an enigmatic little animal like *P. californica*? Most of us might view work on the larval development, behavior, or identification of a worm as being rather esoteric. Given, however, what we know about the ecological requirements and behavior of *P. californica*, such species have excellent potential as, for example, pollution indicators. Organisms living in the intertidal zone are subject not only to the natural hazards of this habitat, but also to the many abuses of humans. Studies on species related to *P. californica* have shown that larvae are extremely sensitive to the presence of pollutants on the surfaces of potential settling sites, and can be killed upon contact with such substances. Such a degree of sensitivity affords us a very good gauge of how we are treating our environment.

KIRK FITZHUGH
Assistant Curator
Section of Invertebrate Zoology

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Southland Diorama is a new TERRA column that highlights the incredible diversity of animal and plant life still to be found in southern California. Each issue will feature an example of one of the many species — extant and extinct, native and introduced, abundant and endangered — that are found in astonishing variety in one of the world's largest urban centers.

CHILE AND ARGENTINA

November 11-21, 1992

From Santiago, bordered by the soaring Andes, fly to Punta Arenas. Study the natural history and native peoples of Patagonia and Tierra del Fuego. Visit Paine Towers National Park, South America's largest and finest wildlife preserve. Visit Puerto Montt before concluding your stay in cosmopolitan Buenos Aires. **\$3,100 plus air fare.**

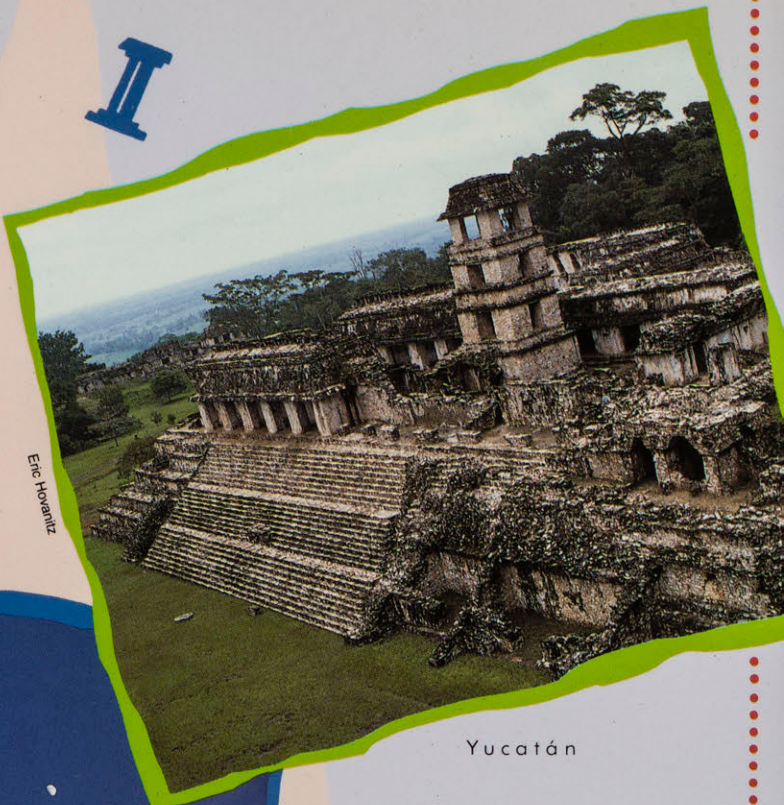
YUCATÁN, LAND OF THE ANCIENT MAYA

November 30-December 13, 1992

Each site on our tour has been carefully chosen to reveal a different facet of the history, religion and art of the Maya and Olmec civilizations, including the magnificent ceremonial centers of Uxmal, Chichen Itza, Tulum, and Palenque. **\$2,495 plus air fare.**



Eric Hovanitz



Yucatán



Yucatán

Eric Hovanitz

Please note: Dates, schedules, program details, and cost, based on information available August 1, 1991, are subject to change and revision.

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PROJECT ANTARCTICA

January 6-20, 1992

Retrace the routes of polar explorers and discover the world's last unspoiled wilderness aboard the "Society Explorer." Visit rookeries of chinstrap, macaroni and Adélie penguins and watch bellowing seals close at hand during Antarctica's austral summer.

From \$5,950 plus air fare.

EVERGLADES AND FLORIDA KEYS

January 24-February 2, 1992

Explore coral reefs, barrier islands, mangrove swamps, and sawgrass prairies in Everglades National Park and the Florida Keys. Photograph the herons, otters, alligators and manatees that make this subtropical wilderness their home.

\$1,573 plus air fare.

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MUSEUM TRAVEL PROGRAM
1992

MEXICO MONARCH BUTTERFLY SAFARI

February 1-6, 1992

View tens of millions of monarch butterflies in their overwintering grounds in the mountains of Michoacán. Opportunities to visit the National Museum of Anthropology, Ballet Folklorico and Templo Mayor in Mexico City included.

\$975 plus air fare of \$355.

YELLOWSTONE IN WINTER

February 9-15, 1992

Discover the beauty of winter in the world's first National Park. Traveling by snow coach and sleigh, view the moose, bison, Canada geese, bald eagles, and trumpeter swans attracted by the year-round warmth of Yellowstone's geysers and fumaroles.

\$1,394 plus air fare.

EXPLORING THE MAYA COAST

February 15-22, 1992

Much of the eastern coast of Middle America remains a genuine wilderness, with dense tropical forest, abundant bird life and one of the world's finest coral reef systems. Explore the land where the Maya flourished 1500 years ago from aboard the 80 passenger "Polaris."

From \$2,520 plus air fare.

NATURE'S ISLAND KINGDOMS

April 7-30, 1992

A voyage to Indonesia, Borneo and the Philippines aboard the new expedition ship "Aurora." In Indonesia, call at Bali, Komodo, Lombok, and Java, before sailing on to Krakatoa. Tour Singapore, then Borneo, with its orangutan preserve. Collect shells in the Philippines before concluding your voyage in Hong Kong.

From \$8,790 plus air fare.

COPPER CANYON, MEXICO

April 12-19, 1992

Ride the world-renowned "Ferrocaril al Pacifico" Railroad through Mexico's spectacular Copper Canyon. Observe the Tarahumara Indians in their celebration of "Semana Santa," the holy Easter week.

\$1,595 plus train fare.

LOUISIANA IN SPRING

April 23-May 1, 1992

Relive the days of antebellum splendor in New Orleans' enchanting courtyards and elegant plantations during the azalea-filled spring, and hear jazz legends during the Jazz Festival. Optional Kentucky Derby Cruise aboard the "Delta Queen."

\$1,248 plus air fare.

HOLLAND'S NATURAL SPLENDORS

May 2-14, 1992

Magnificent flora serves as a backdrop to a fascinating study of a land famed for its eternal battle with the sea. A highlight will be a visit to the famed worldwide Floriade Exposition. Visits to castles, gardens, museums and pristine natural areas also included.

\$3,650 including air fare.

THE ISLANDS OF INDONESIA

June 8-24, 1992

Explore mountainous Sumatra, home of the fascinating Batak tribes and the endangered red orangutan. Tour Hindu and Buddhist temples in Java and browse among shops filled with exquisite folk art and batik. Enjoy Bali, magical haven for the arts.

\$3,238 plus air fare.

GREENLAND AND THE CANADIAN ARCTIC

July 10-20, 1992

Take in this remote land of ice from aboard the "Illiria." Explore the coast of Greenland and Canada's Baffin Island by Zodiac. Wildlife may be present in incredible abundance, including polar bear, arctic fox and hare, and at sea, seals and whales.

From \$3,995 plus air fare.

ZIMBABWE

July 24-August 8, 1992

From the woodlands of the Zambezi River Valley, across the deep sands of the Kalahari desert, to the rainforested lip of Victoria Falls, Zimbabwe is safari land in perfection. Here are the last remaining strongholds of African elephant and black rhino. Optional extension to Botswana.

\$5,198 including air fare.

ALASKA AND BRITISH COLUMBIA

August 29-September 11, 1992

This special voyage aboard the 70 passenger "Sea Lion" offers an in-depth exploration of the coastal wilderness of southeast Alaska and British Columbia, from Glacier Bay to Vancouver, including the magnificent, seldom visited Queen Charlotte Islands.

From \$3,690 plus air fare.

ANCIENT AND LIVING GREECE

September, 1992

Feel the splendor of ancient Athens. Travel through history to Corinth, Mycenae, Olympia and Delphi, enjoying museums, archaeological sites, Byzantine monasteries and quaint tavernas along the way. Cruise to Mykonos, Santorini, Rhodes, and ancient Ephesus.

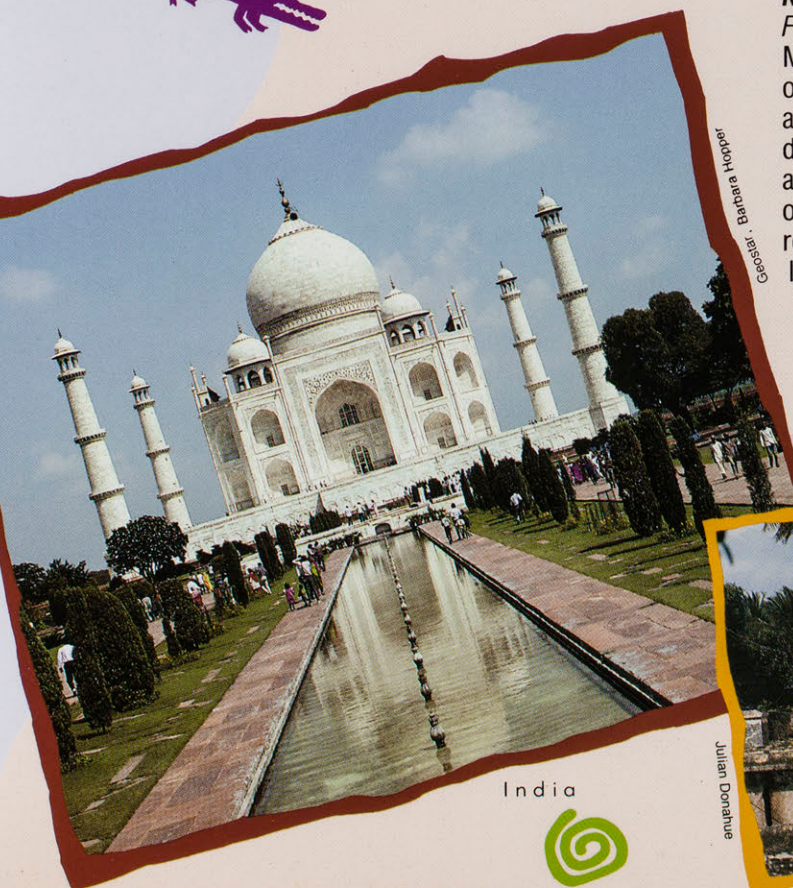
\$2,750 including air fare.

THE TREASURES OF INDIA

October 11-November 9, 1992

Exalt in the natural history and culture of this diverse country, where 5,000 years of continuous civilization have left a legacy of temples, monuments and places, as well as internationally recognized wildlife preserves.

\$4,190 plus air fare.



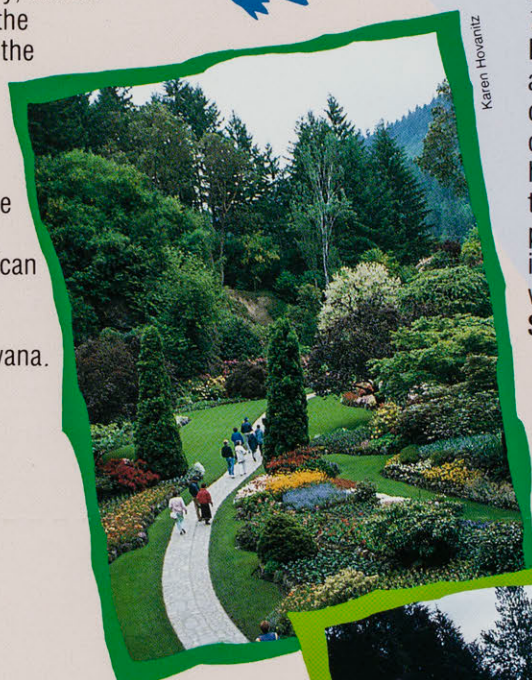
India



India



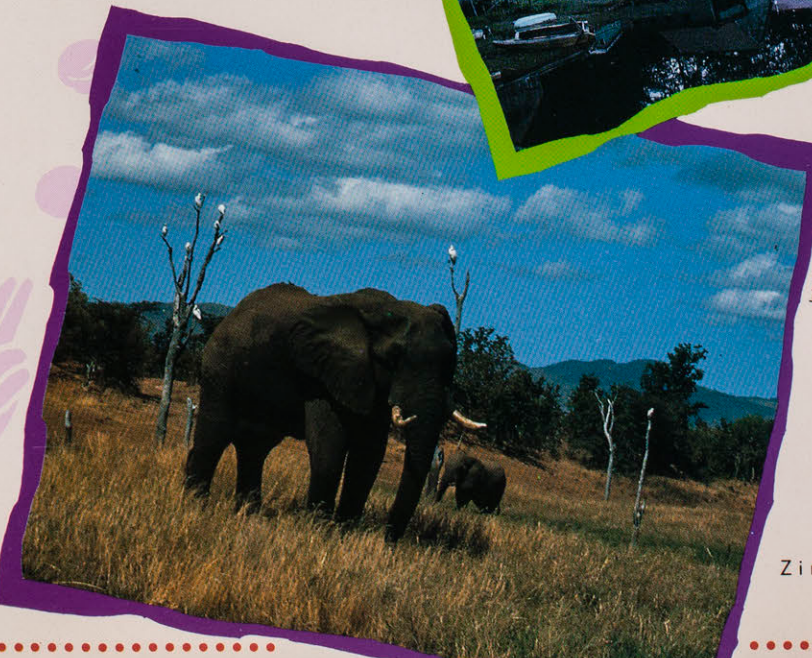
Indonesia



Alaska



Alaska

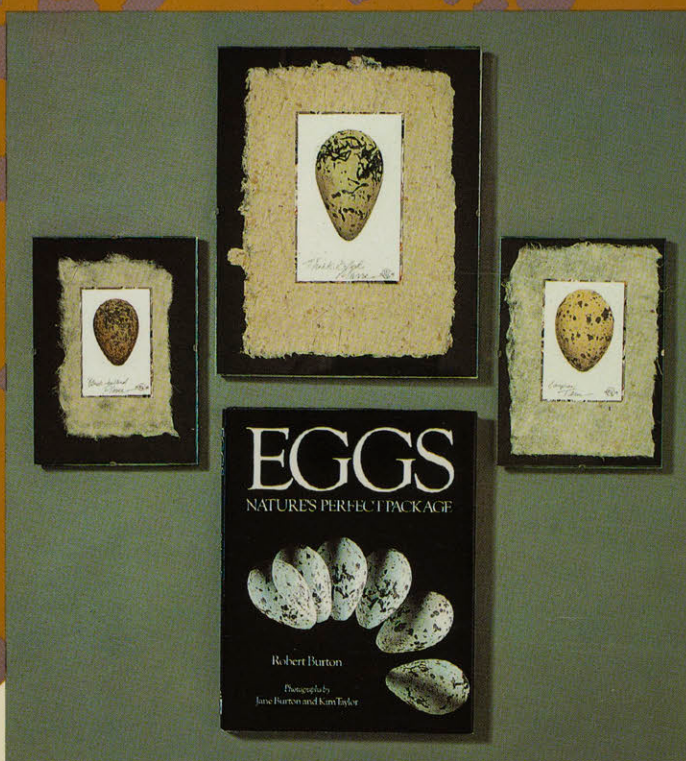


Zimbabwe



THE MUSEUM BOOKSTORE

Offers the opportunity to learn more about eggs and
to marvel at their amazing diversity...



EGGS

NATURE'S PERFECT PACKAGE

This lavishly illustrated book explores and explains the staggering variety of strategies employed by animals in producing, fertilizing, laying, and caring for their eggs, and the wonderful diversity of their form, from the tiny sculptured button of a butterfly egg to the perfect oval of a bird's egg. Hardcover, 158 pages, \$24.95.

EGG ILLUSTRATIONS

Nature artist Maryjo Koch of Santa Cruz, California recreates the tactile beauty of North American bird eggs in her original illustrations of eggs from established museum collections. The unique colors and patterns of individual eggs are painted with water color, gouache, and pencil, then framed under glass with handmade papers. Each egg is identified alongside the artist's signature, and no two are alike. Small 5" x 7" illustrations, \$25.00. Large 8" x 10" illustrations, \$35.00.

Both the book *Eggs: Nature's Perfect Package* and Maryjo Koch's egg illustrations are available in the Museum Bookstore located at the north entrance of the Museum. To order by telephone, call 213/744-3434.

